Japanese Plan : PRISM/PRIME

PRISM

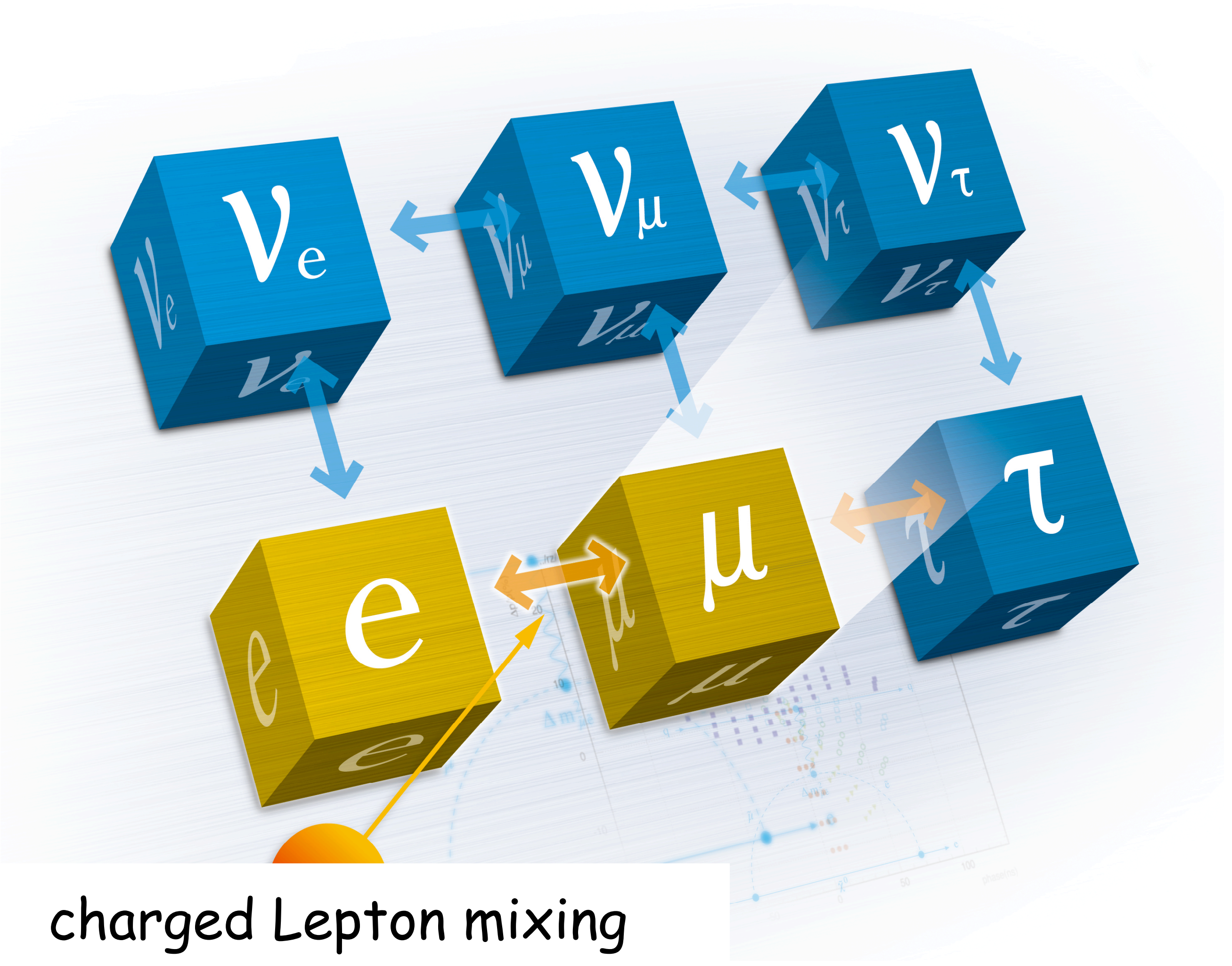
our new logo

Yoshitaka Kuno
Osaka University

September 16th, 2006
Mu2E workshop at Fermilab

Outline

- Why Aim at s Sensitivity of 10^{-18} ?
- What is PRISM ? What is PRIME ?
- PRISM R&D and Design
- Prospects
- Summary and Outlook



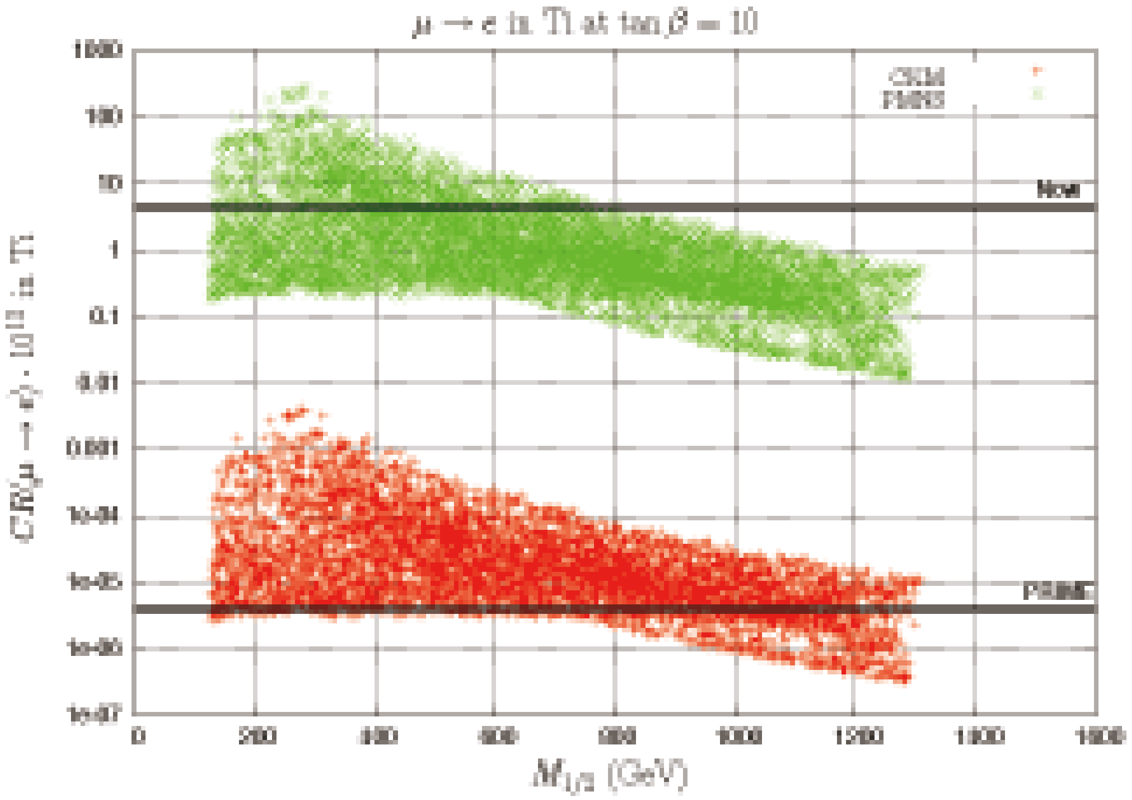
charged Lepton mixing

PRISM

Why Aim for
a Sensitivity of 10^{-18} ?

SUSY-GUT Prediction for μ-e Conversion (for SUSY parameters by LHC)

low tanβ

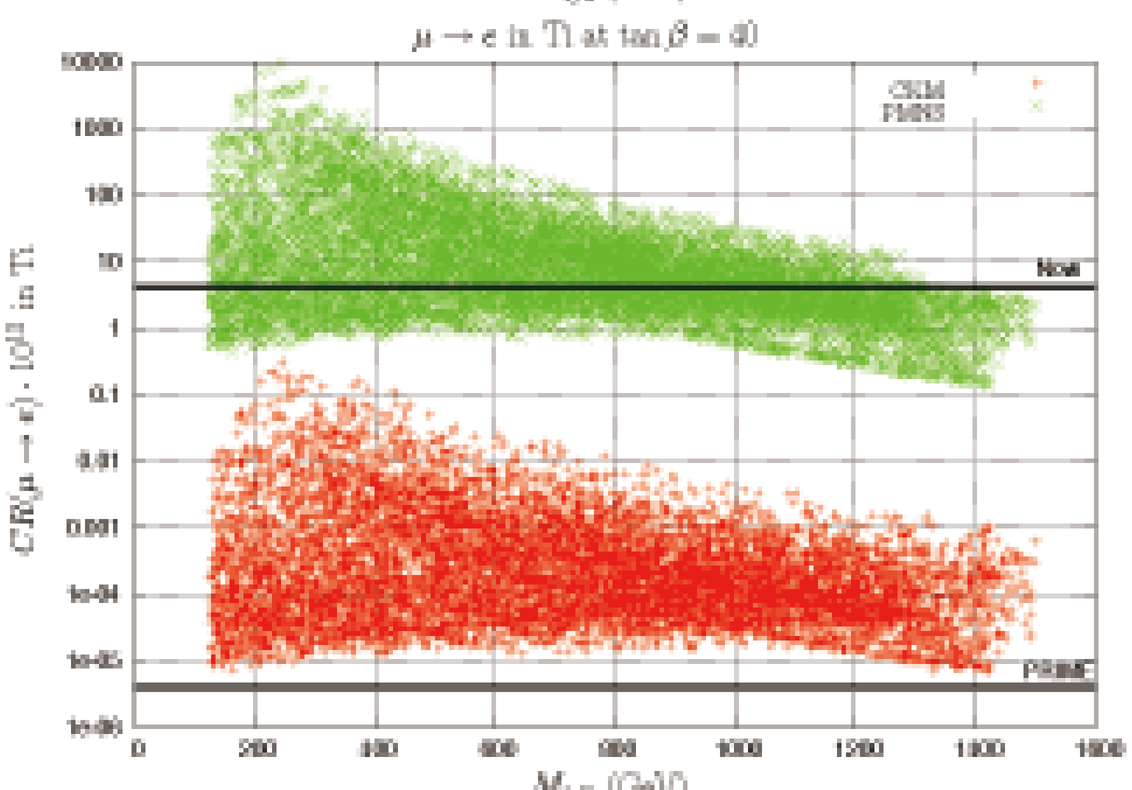


10^{-12}

10^{-18}

A. Masiero et al.

high tanβ



10^{-12}

10^{-18}

LHC, SUSY and Charged Lepton Mixing

LHC, SUSY and Charged Lepton Mixing

If LHC finds SUSY

LFV search would become important, since the slepton mixing matrix should be studied.

- SUSY-GUT
- SUSY Seesaw models.

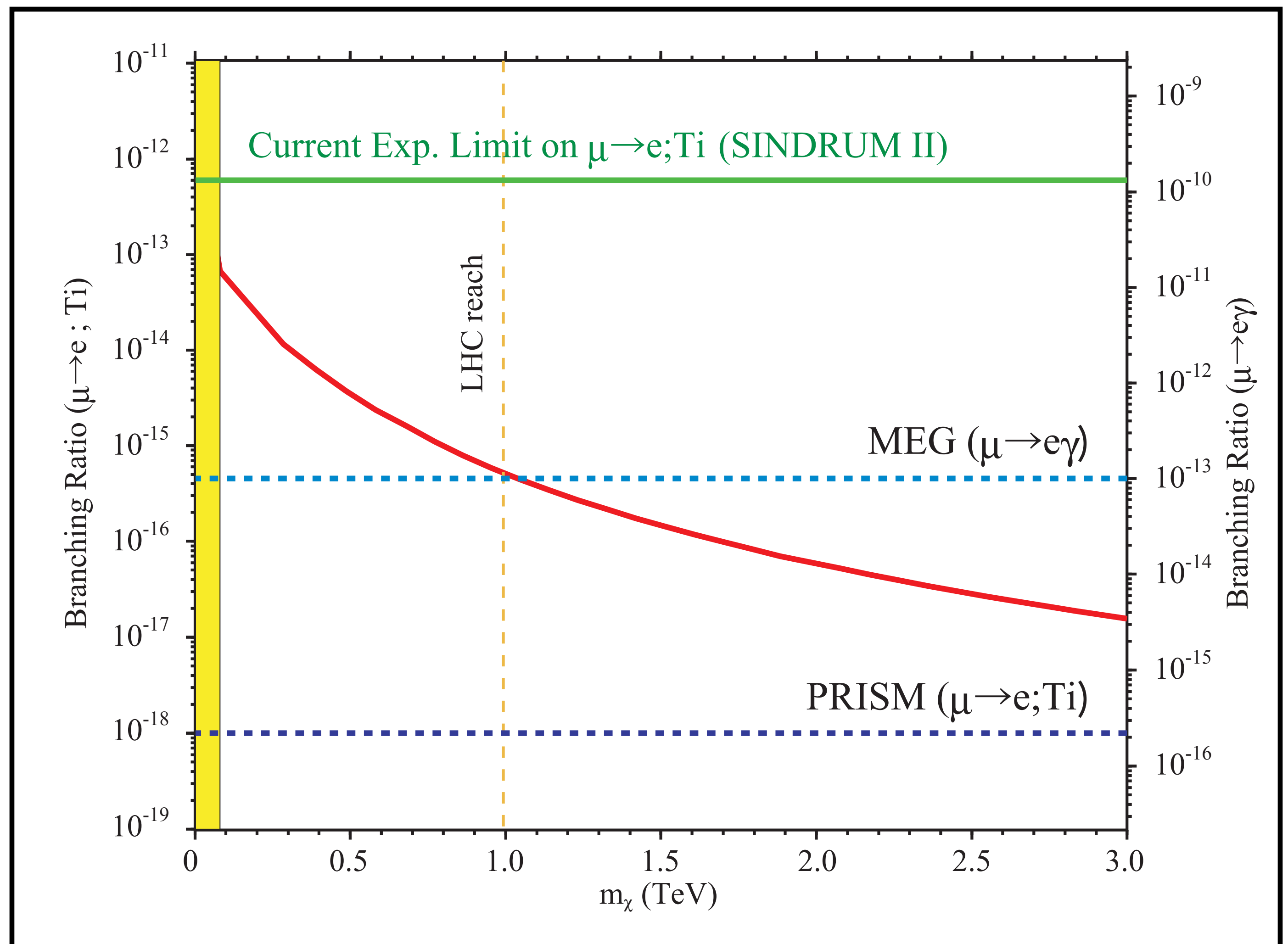
LHC, SUSY and Charged Lepton Mixing

If LHC finds SUSY

LFV search would become important, since the slepton mixing matrix should be studied.
- SUSY-GUT
- SUSY Seesaw models.

If LHC not find SUSY

LFV search would be sensitive to multi-TeV SUSY.



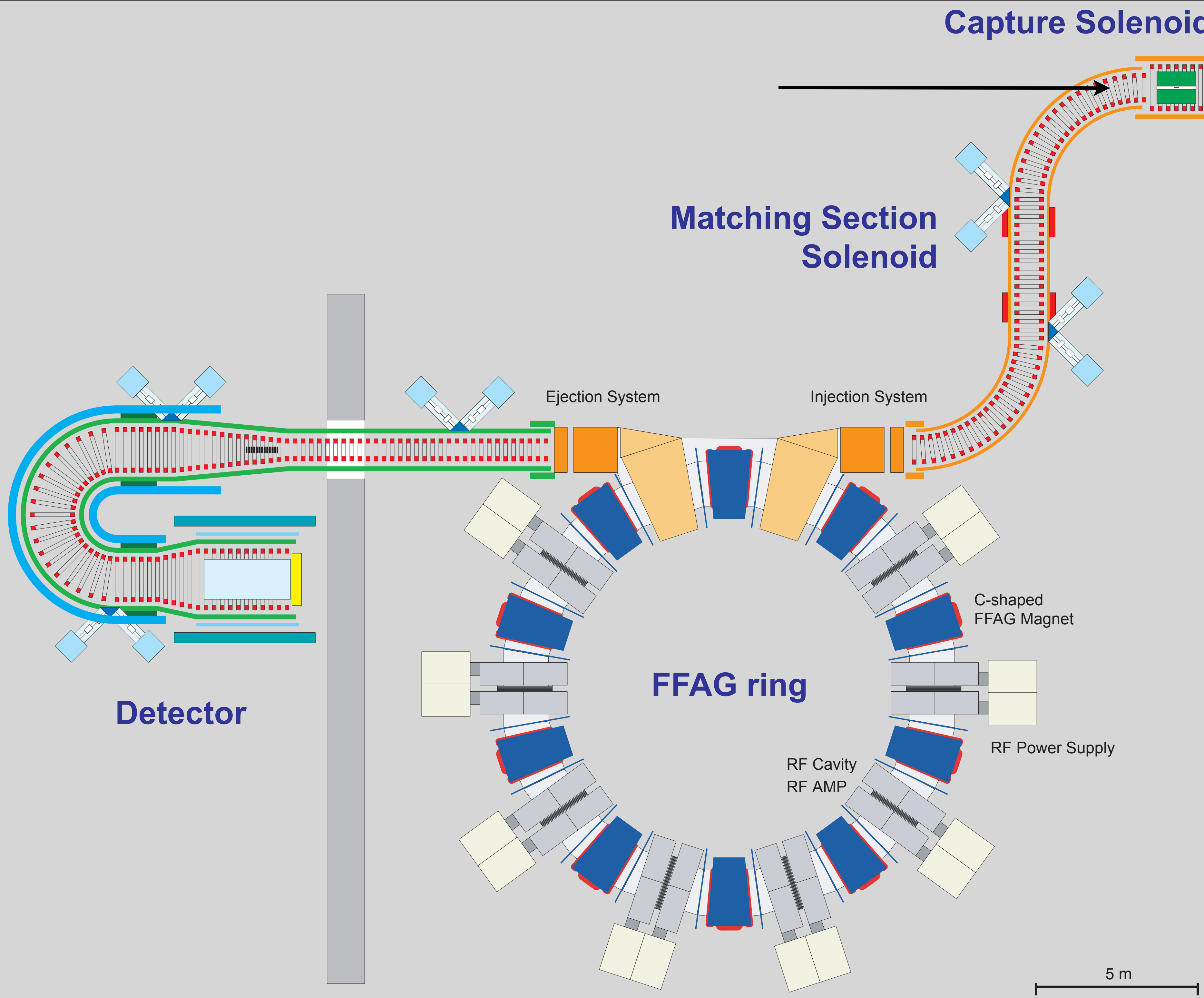
from A.Masiero et al.

What is PRISM ?

What is PRIME ?

What is PRISM ?

- PRISM is a next-generation muon beam facility, considered in Japan.
- PRISM stands for Phase Rotated Intense Slow Muon source.
- PRISM has features of
  - high intensity (pion solenoid capture)
  - high luminosity (narrow beam energy spread)
  - high purity (no pion contamination).
- PRISM consists of
  - pion capture section
    - superconducting solenoid magnets
    - mag. field of from 6 T to 20 T (depends on technology and cost)
  - transport section
    - curved solenoid
  - muon storage ring section
    - a FFAG ring with large acceptance.



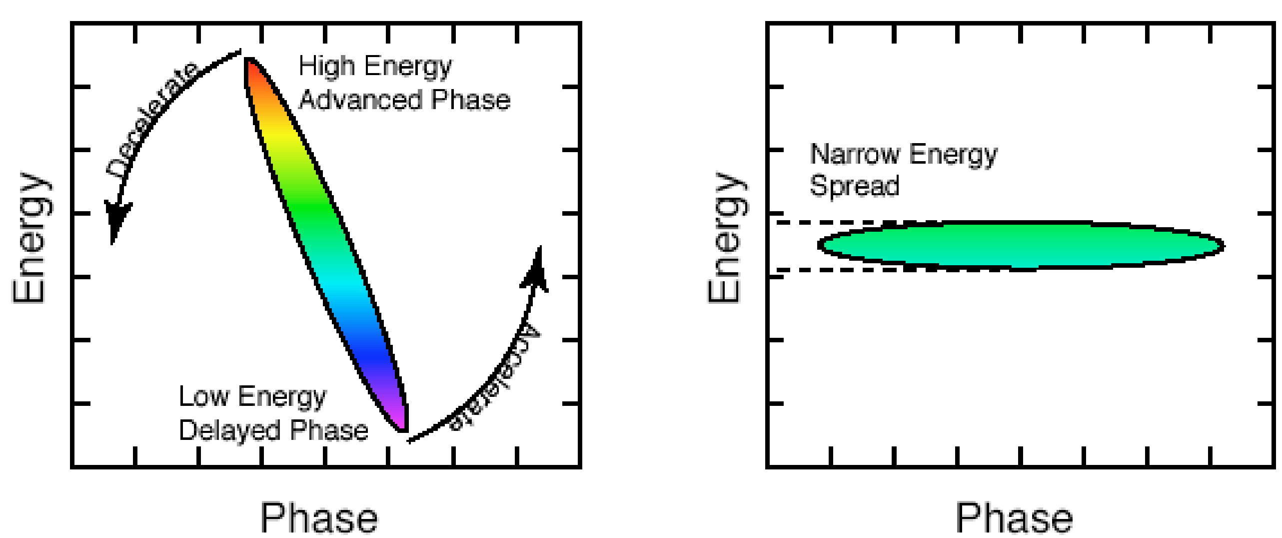
PRISM Layout

There are commonality and difference from MELC/MECO/Me2E.

PRISM

... To Make Narrow Beam Energy Spread

- A technique of phase rotation is adopted.
- The phase rotation is to decelerate fast beam particles and accelerate slow beam particles.
- To identify energy of beam particles, a time of flight (TOF) from the proton bunch is used.
  - Fast particle comes earlier and slow particle comes late.
- Proton beam pulse should be narrow (< 10 nsec).
- Phase rotation is a well-established technique, but how to apply a tertiary beam like muons (broad emittance) ?



Phase Rotation for a Muon Beam

PRISM

Use a muon storage ring ?

(1) Use a muon Storage Ring :

A muon storage ring would be better and realistic than a linac option because of reduction of # of cavities and rf power.

(2) Rejection of pions in a beam :

At the same time, pions in a beam would decay out owing to long flight length.

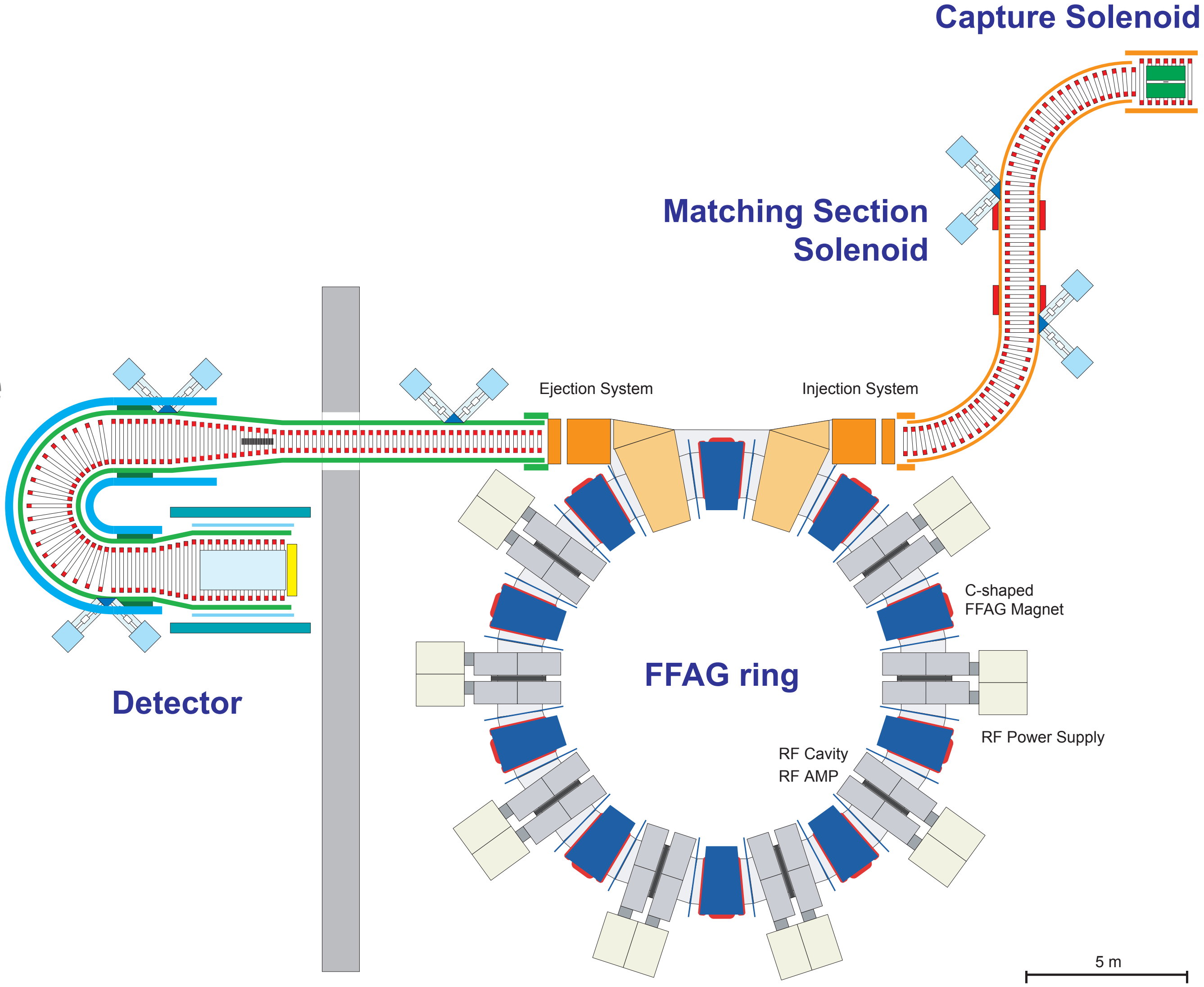
Which type of a storage ring ?

(1) cannot be cyclotron, because of no synchrotron oscillation.
(2) cannot be synchrotron, because of small acceptance and slow acceleration.

Fixed field Alternating Gradient Ring (FFAG)

PRISM Specifications

- Intensity :
  - 10^{11}-10^{12} muons/sec.
  - for a MW proton beam power
- Central Momentum :
  - 68 MeV/c
  - lower than 77 MeV/c
- Momentum Spread :
  - ±3% (from ±30% after phase rotation.)
- Beam Repetition
  - 100 - 1000 Hz
  - due to repetition of kicker magnets of the muon storage ring.
- Beam Energy Selection
  - 68 MeV/c ±3%
  - at extraction of the muon storage ring.



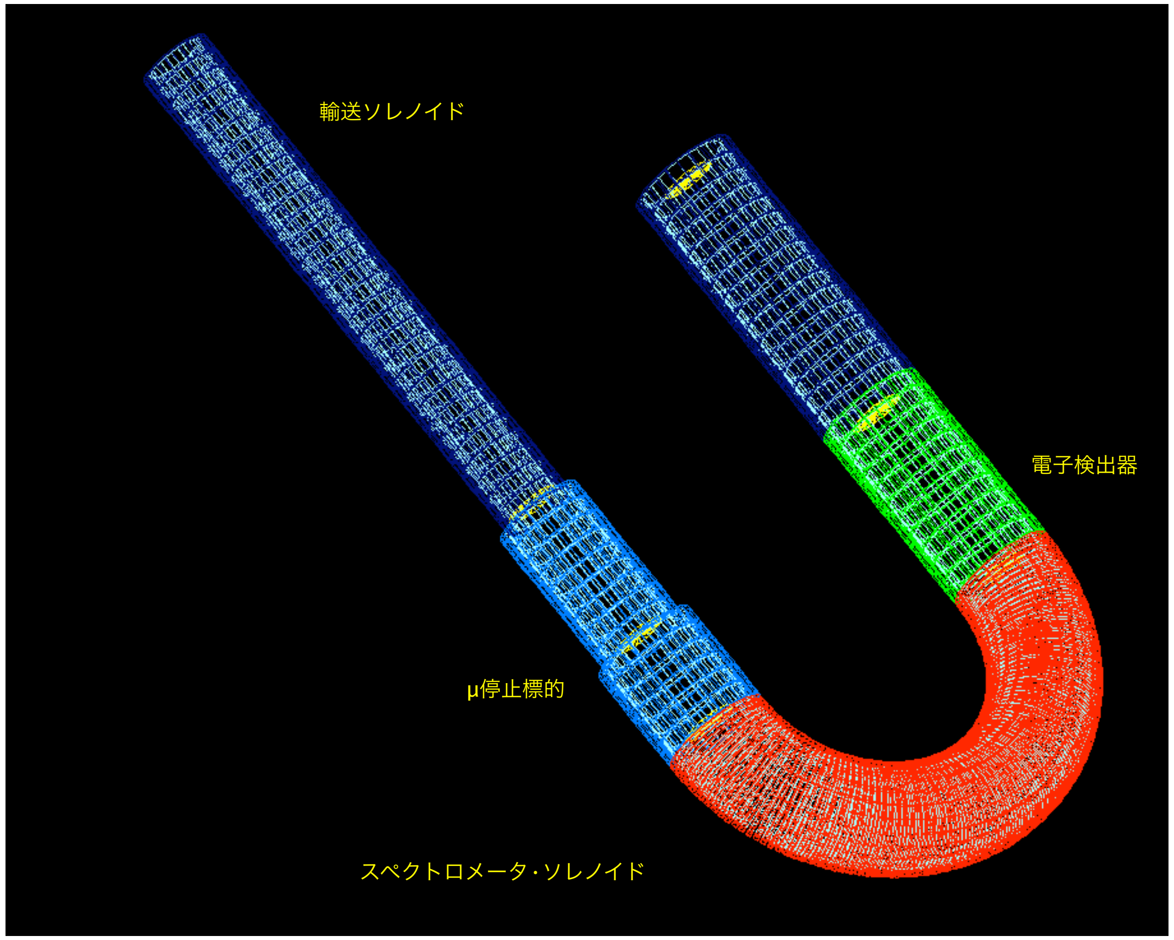
PRIME Detector

PRIME=PRISM Mu E conversion detector

PRISM

- High single rates in the detector could cause false tracking, mimicking the signal.
- Sources of the detector rates
  - electrons from bound muon decays, and others.
- MECO :
  - a straight solenoid
  - P_T cut only (P_T>55 MeV/c)
  - Rates of tracking wire chambers ~ 500 kHz/wire
- PRIME :
  - many muons/bunch
  - beam repetition 100-1000Hz

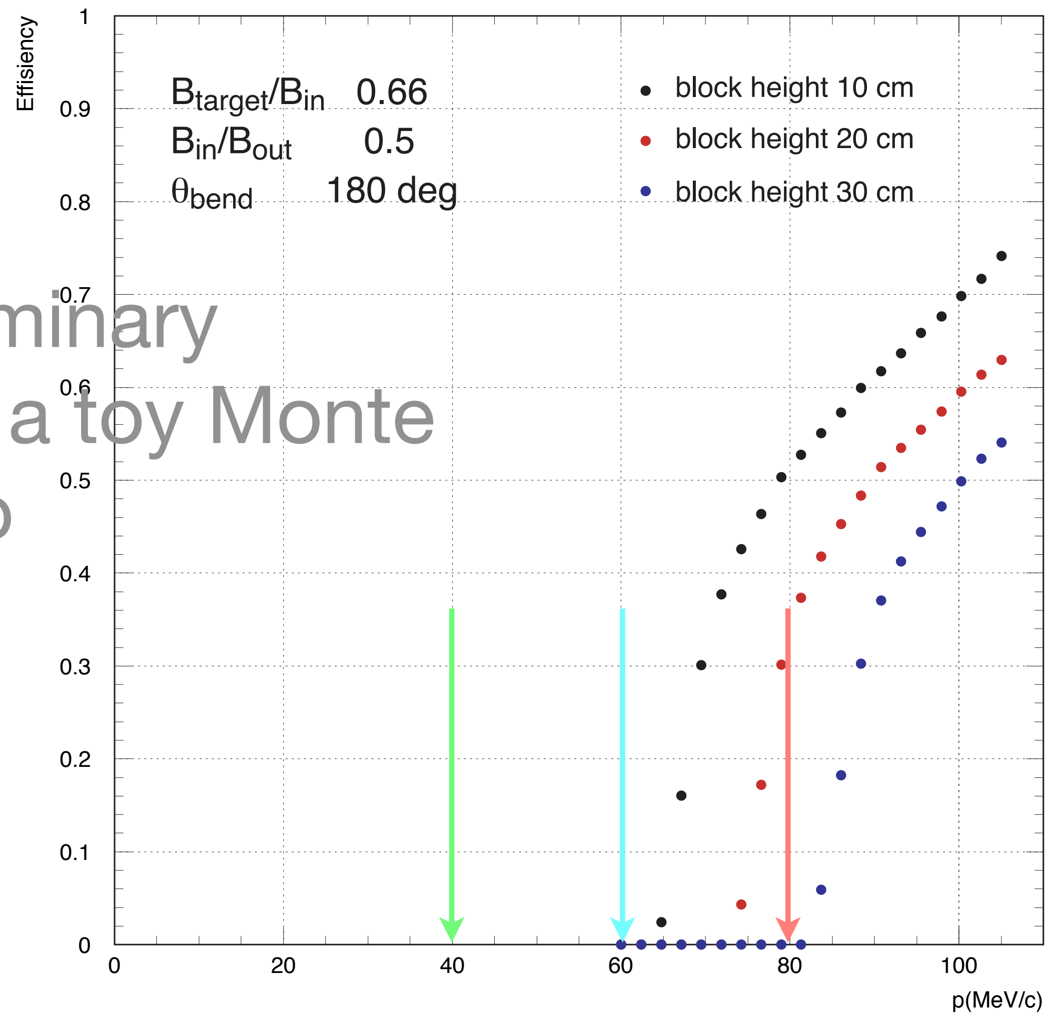
- Curved Solenoid
- vertical drift is used for momentum and charge selection.
- T-type trackers



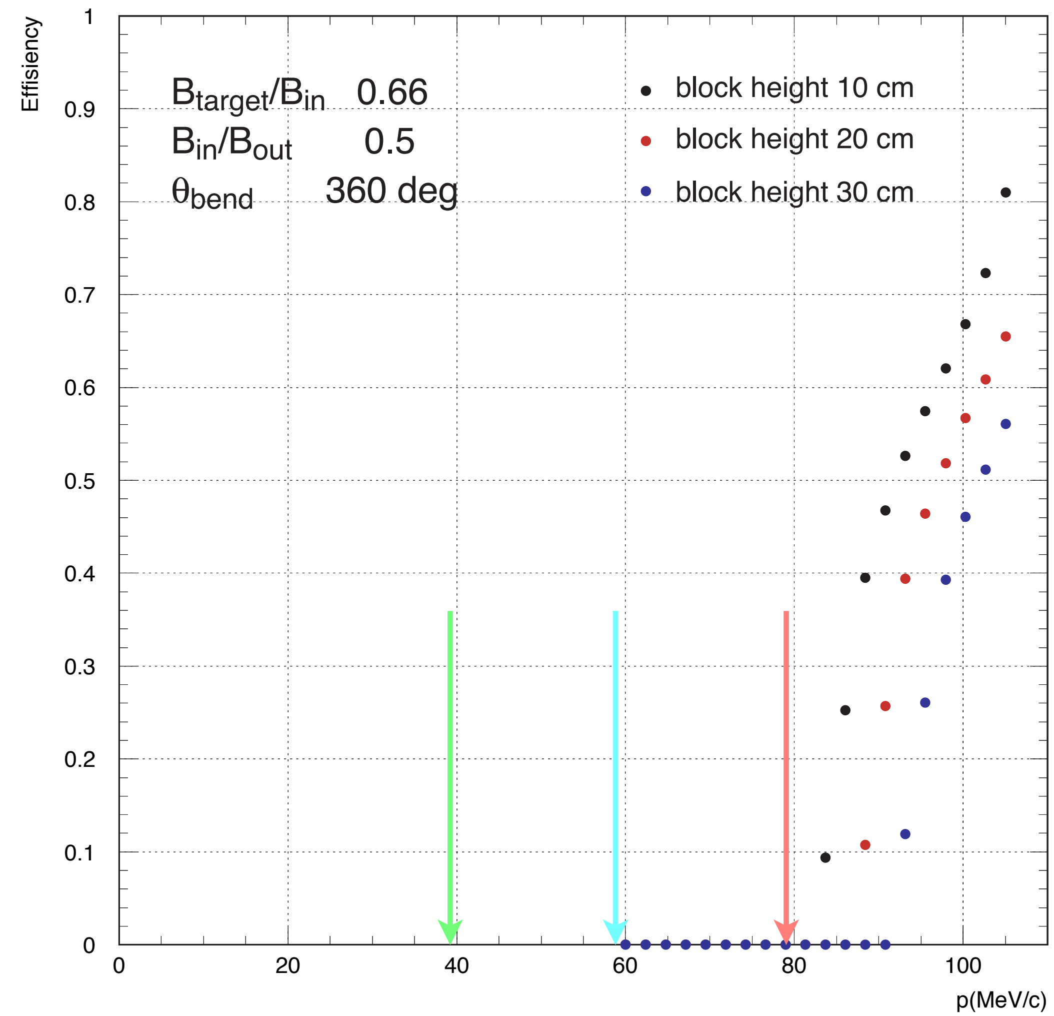
Rejection of Electrons from Bound Muon Decay

Preliminary
from a toy Monte Carlo

Bin,Btarget,Bout=3,2,1T



θbend=180 deg



θbend=360 deg

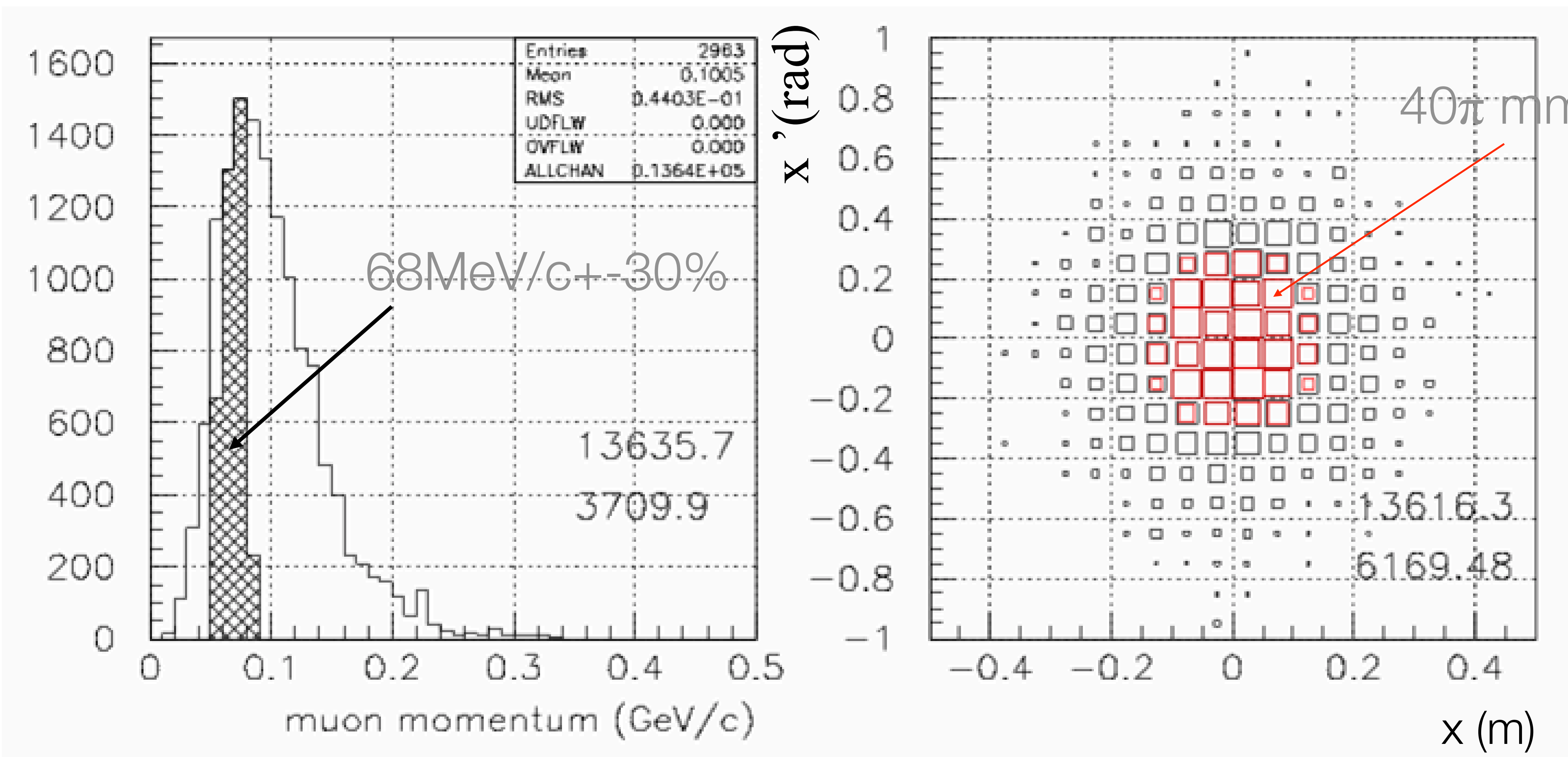
threshold	rate with 100 bunches/sec	rate with 1000 bunches/sec
70 MeV	700 hits /plane/bunch	70 hits/plane/bunch
80 MeV	20 hits /plane/bunch	2 hits/plane/bunch
90 MeV	0.2 hits /plane/bunch	0.02 hits/plane/bunch

from BMD only

PRISM

Muon Yield Simulation with MARS and GEANT

- a 40-GeV proton beam on 60 cm-long graphite target under 6 T.
- with momentum selection (68MeV/c+-30%)
- with FFAG-acceptance (40π mm rad in horizontal, 6.5π mm rad in vertical)
- 6×10^{10} μ^-/sec, assuming 0.6MW beam power



350k POT

Muon Yield Estimation at PRISM

based on the PRISM FFAG acceptance of 40 mm rad in horizontal and 6.5 mm rad in vertical and a muon stopping target of 1/10 thickness of MECO.

Cases	Proton Beam Power	Target Material	Pion Capture Magnetic Field	Muon Yield (/sec)
1	0.6 MW	Graphite	6 T	7×10^{10}
2	0.6 MW	Graphite	16 T	2×10^{11}
3	0.6 MW	Tungsten	6 T	2×10^{11}
4	0.6 MW	Tungsten	16 T	5×10^{11}
5*	4 MW	Mercury	6 T	1×10^{12}
6*	4 MW	Mercury	16 T	3×10^{12}

from the PRISM/PRIME LOI (2006)

Muon Yield Estimation at PRISM

based on the PRISM FFAG acceptance of 40 mm rad in horizontal and 6.5 mm rad in vertical and a muon stopping target of 1/10 thickness of MECO.

Cases	Proton Beam Power	Target Material	Pion Capture Magnetic Field	Muon Yield (/sec)
1	0.6 MW	Graphite	6 T	7×10^{10}
2	0.6 MW	Graphite	16 T	2×10^{11}
3	0.6 MW	Tungsten	6 T	2×10^{11}
4	0.6 MW	Tungsten	16 T	5×10^{11}
5*	4 MW	Mercury	6 T	1×10^{12}
6*	4 MW	Mercury	16 T	3×10^{12}

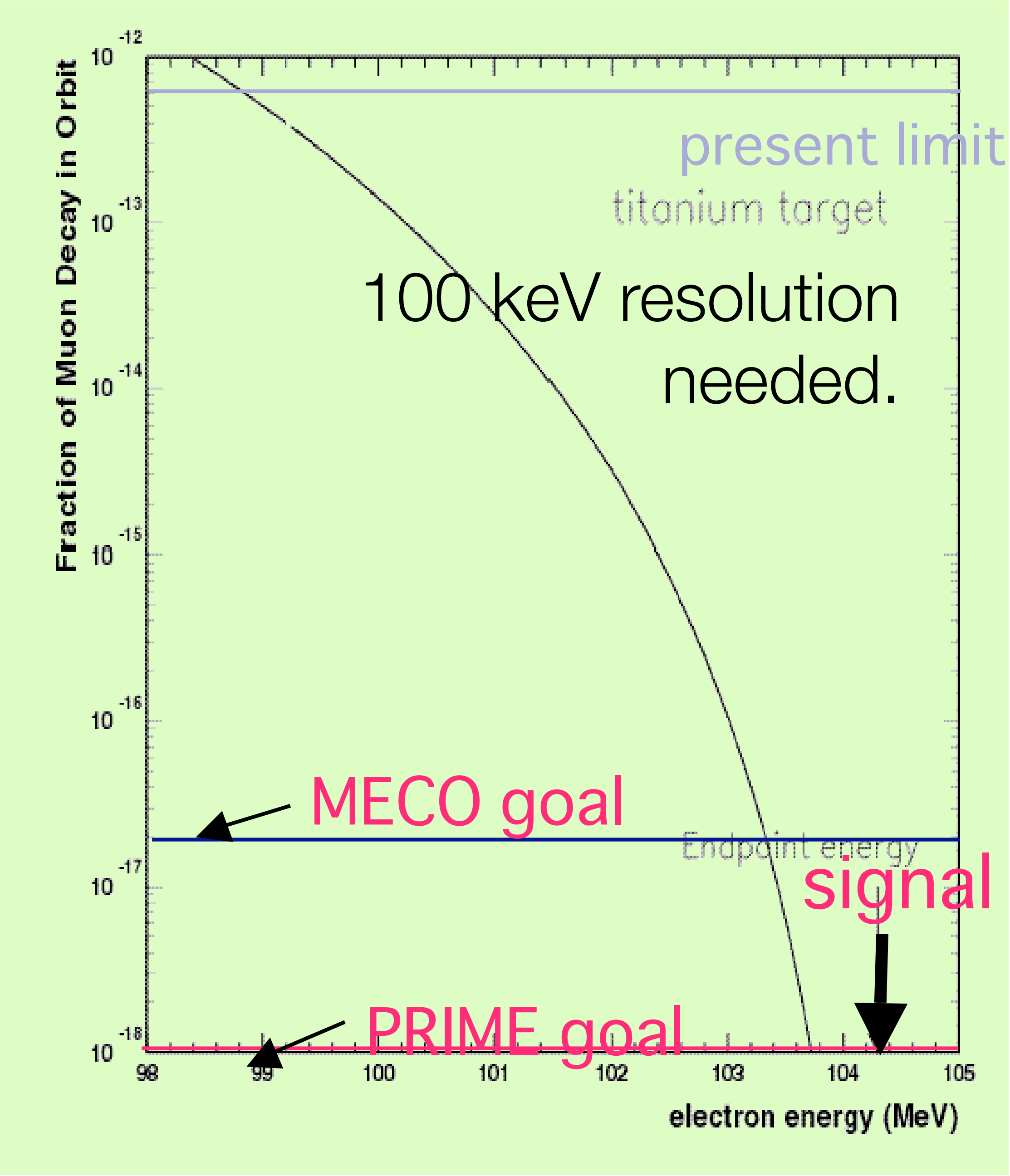
from the PRISM/PRIME LOI (2006)

PRISM/PRIME Sensitivity for μ-e conversion

$$B(\mu^- + Ti \rightarrow e^- + N) > 10^{-18}$$

preliminary

	PRIME
proton beam power	0.6 MW
muon intensity	2 x 10^{11}/sec
acceptance	0.22
time window	100%
running period	5 year
Single Event Sensitivity	6×10^{-19}

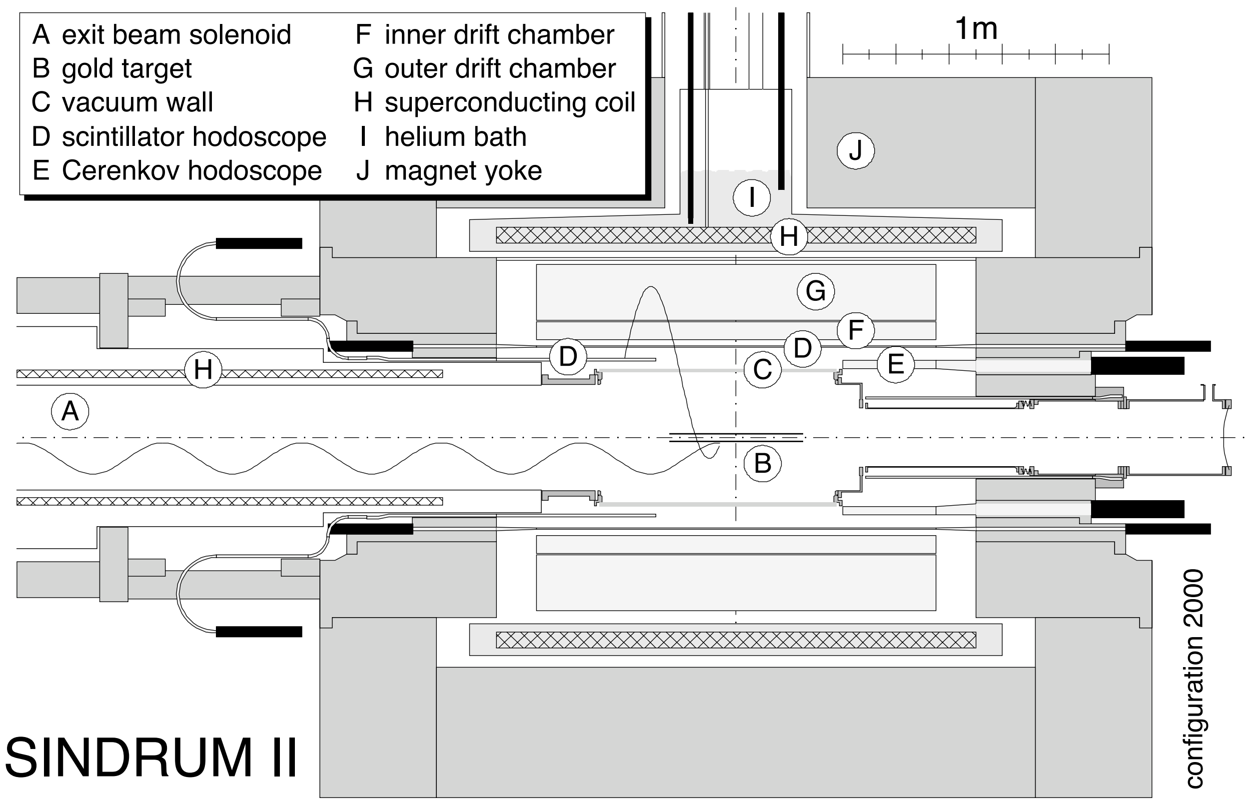


Work in Progress

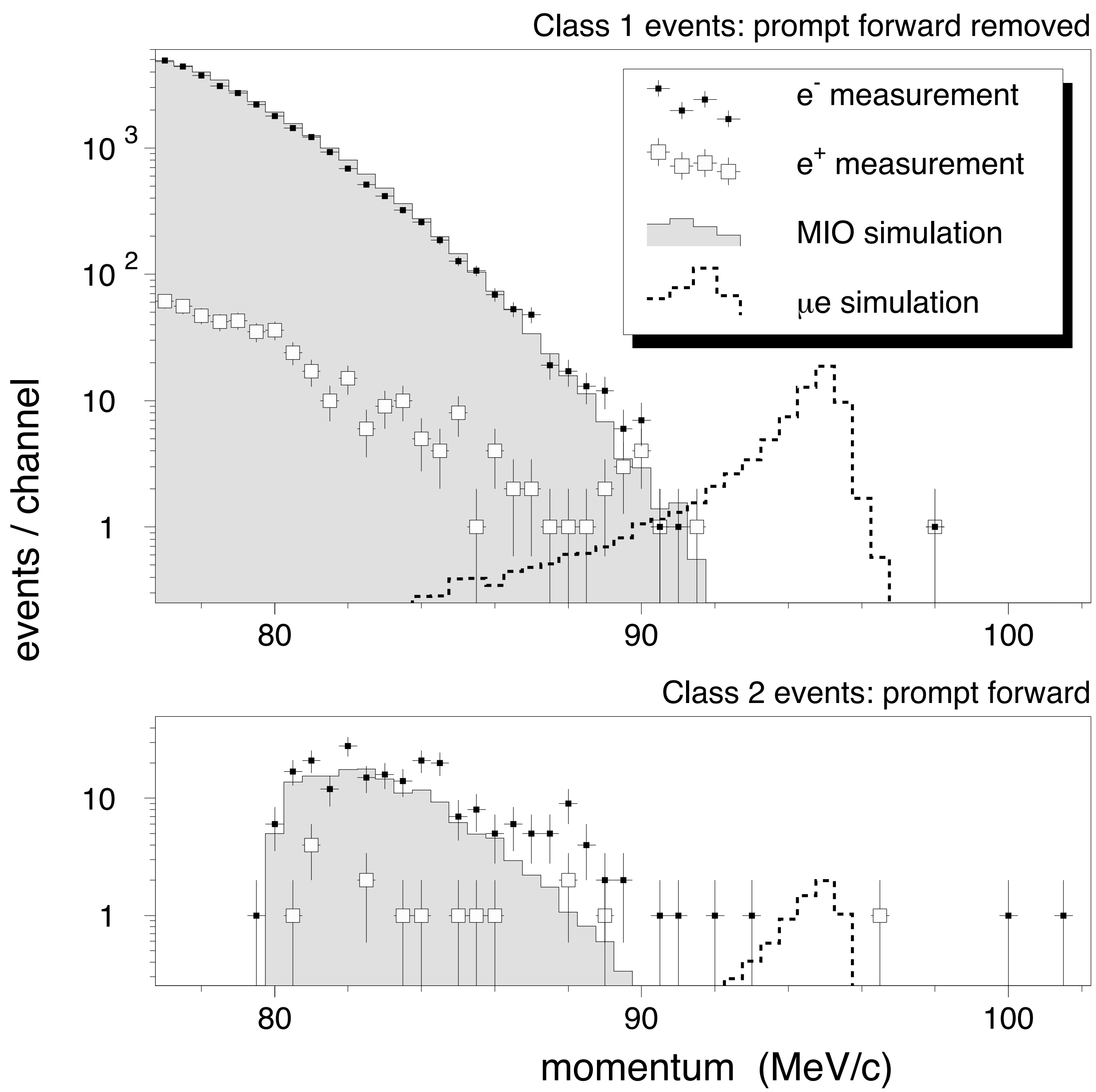
from the PRISM/PRIME LOI (2006)

SINDRUM-II (at PSI)

unpublished



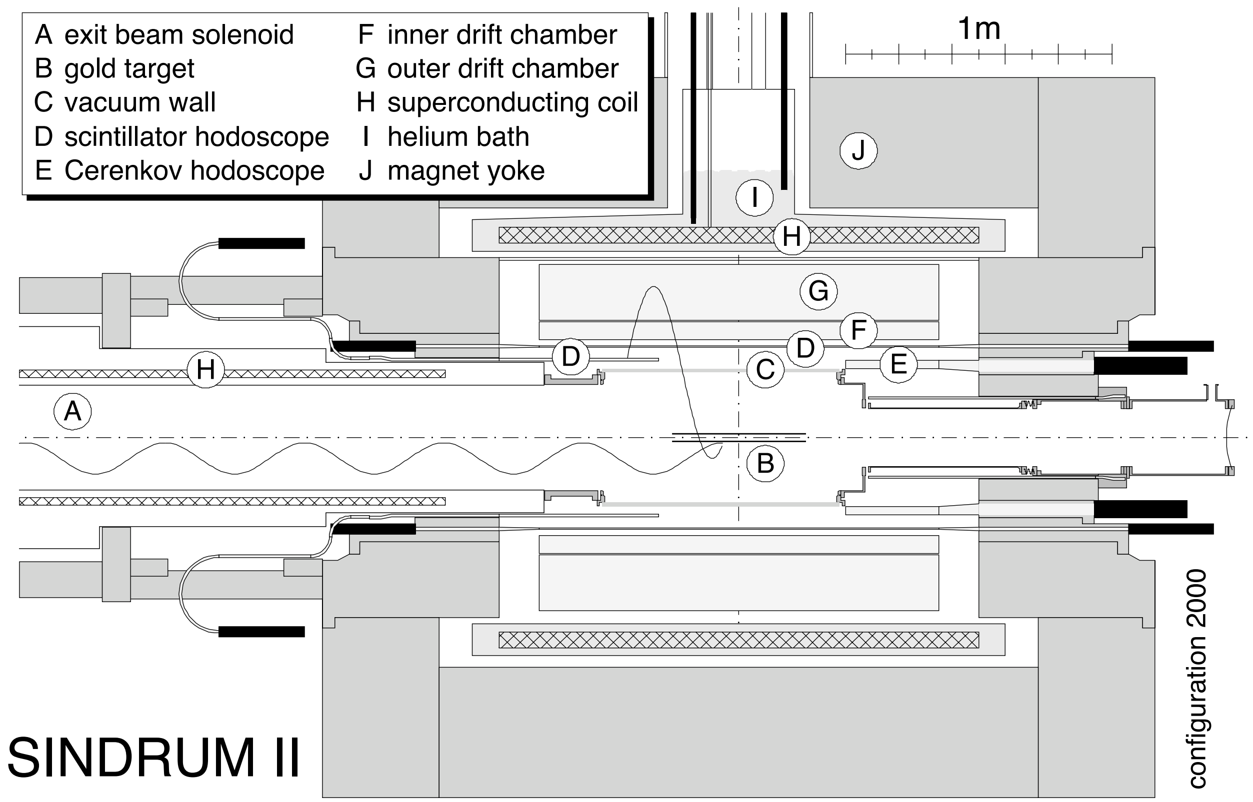
$$B(\mu^- + Au \rightarrow e^- + Au) < 7 \times 10^{-13}$$

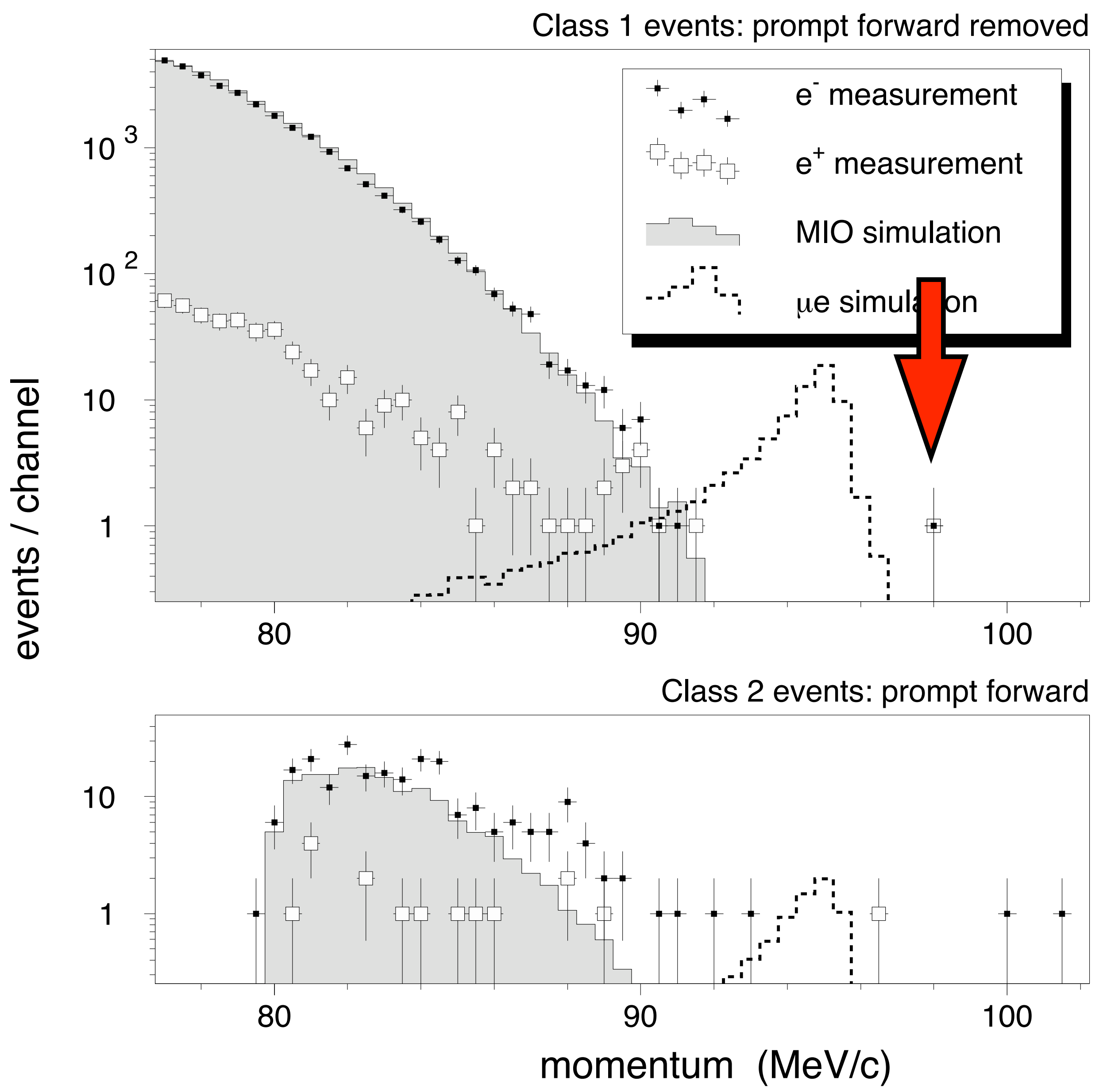


SINDRUM-II (at PSI)

unpublished

$$B(\mu^- + Au \rightarrow e^- + Au) < 7 \times 10^{-13}$$





There is one background event above the signal region, and it is speculated that it might come from pion contamination in a beam.

PRISM Features to Reject Backgrounds

- (1) Long muon flight length
  - about 40 m circumference x 5-6 turns at the muon storage ring (PRISM-FFAG)
  - pion survival rate of $<10^{-20}$
- (2) Narrow muon beam energy spread
  - goal : +- 3 %
  - by phase rotation at the PRISM-FFAG ring
- (3) Muon beam energy selection before the detector
  - momentum slit after the PRISM-FFAG ring
  - 68 MeV/c +- 3% (not 104 MeV)
- (4) Beam extinction at muons
  - Kicker magnets of the PRISM-FFAG ring
  - no proton extinction needed
- (5) Small duty factor of detection
  - ~ 10^{-4} for a detection of 1 μs with 100 Hz repetition

Background Consideration

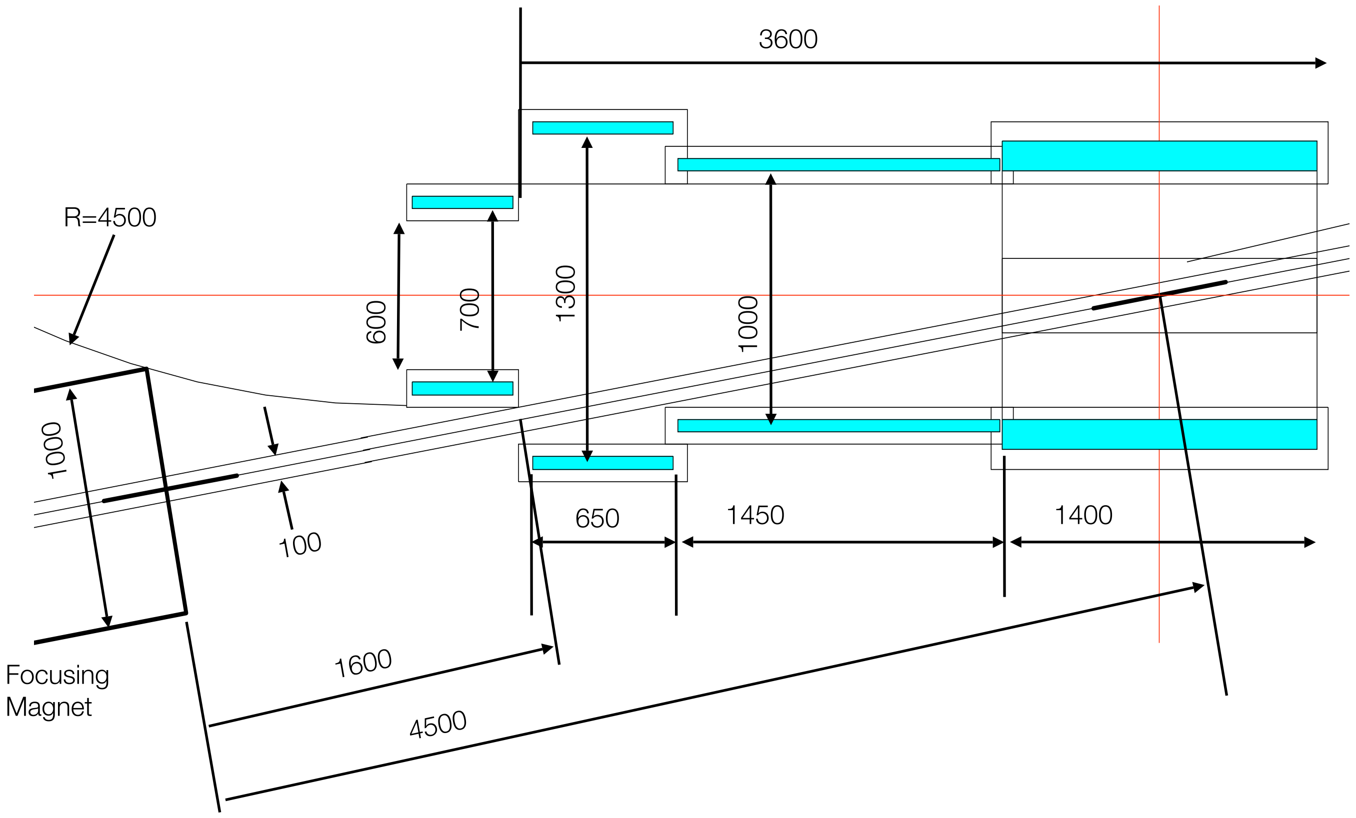
as simple as possible

Source	How to Eliminate	Comments
Bound muon decays	(2) energy spread	1/10 of the MECO target
Radiative pion capture	(1) flight	no pions
Beam electrons	(3) momentum cut	
Muon decay in flight	(3) momentum cut	$P < 77$ MeV/c
Decayed background	(4)	
Cosmic rays	(5)	no active cosmic ray shield needed.

PRISM
R&D and Design

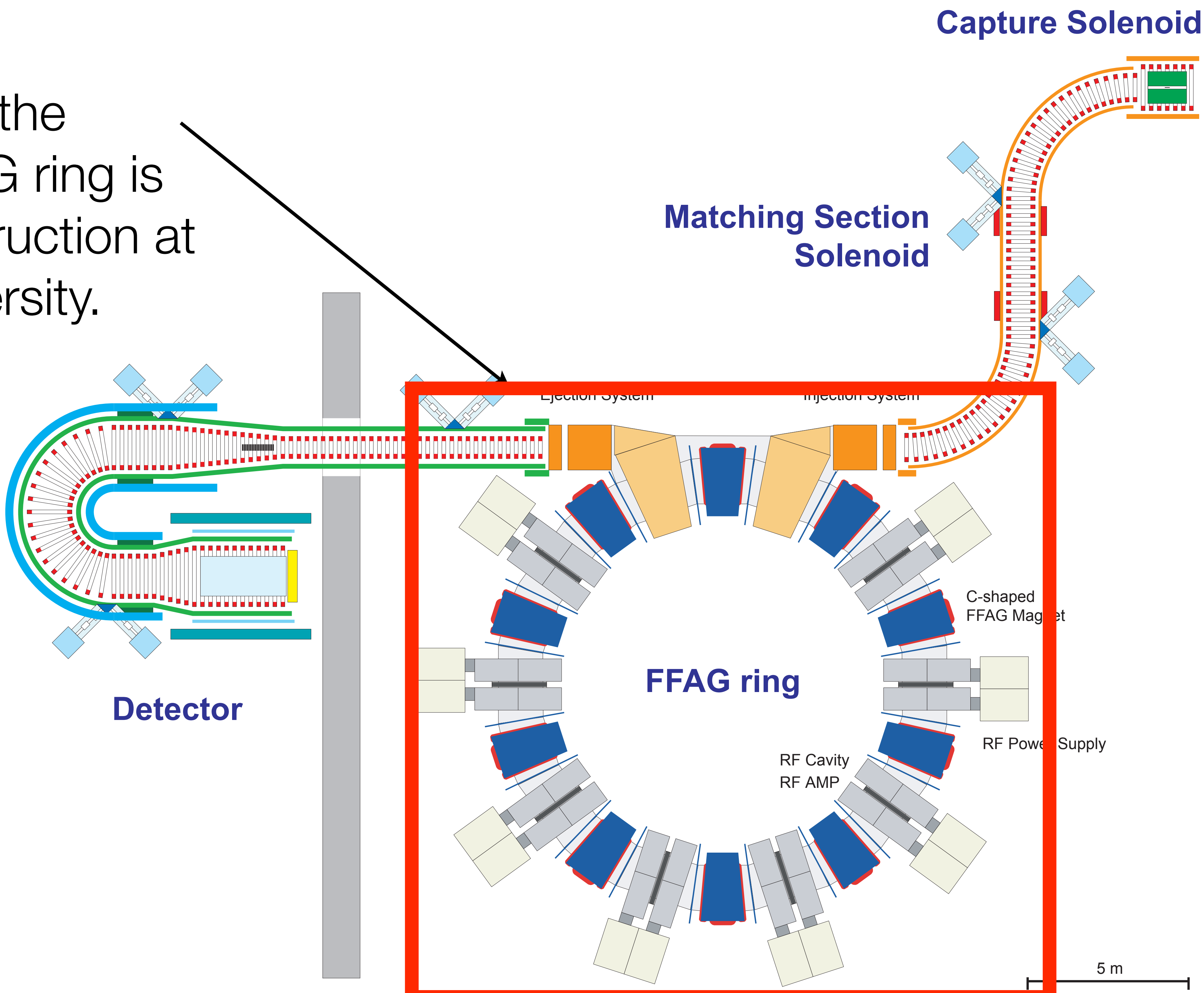
Design of Pion Capture and Transport Sections

- Pion Capture Superconducting solenoid magnet
    - for (0.6) MW beam power
    - 6T magnetic field for the initial stage.
    - Inner bore (R=15cm)
    - aluminum-stabilized coil
        - 5-20 cm thick
        - 140 cm length
    - Radiation shield
        - tungsten (cooled)
        - 25-35 cm radial thickness
- Transport Solenoids
    - Pancakes ?
    - optimization of # of coils.
- Support from the KEK cryogenic group (with Prof. A. Yamamoto)
    - a monthly meeting



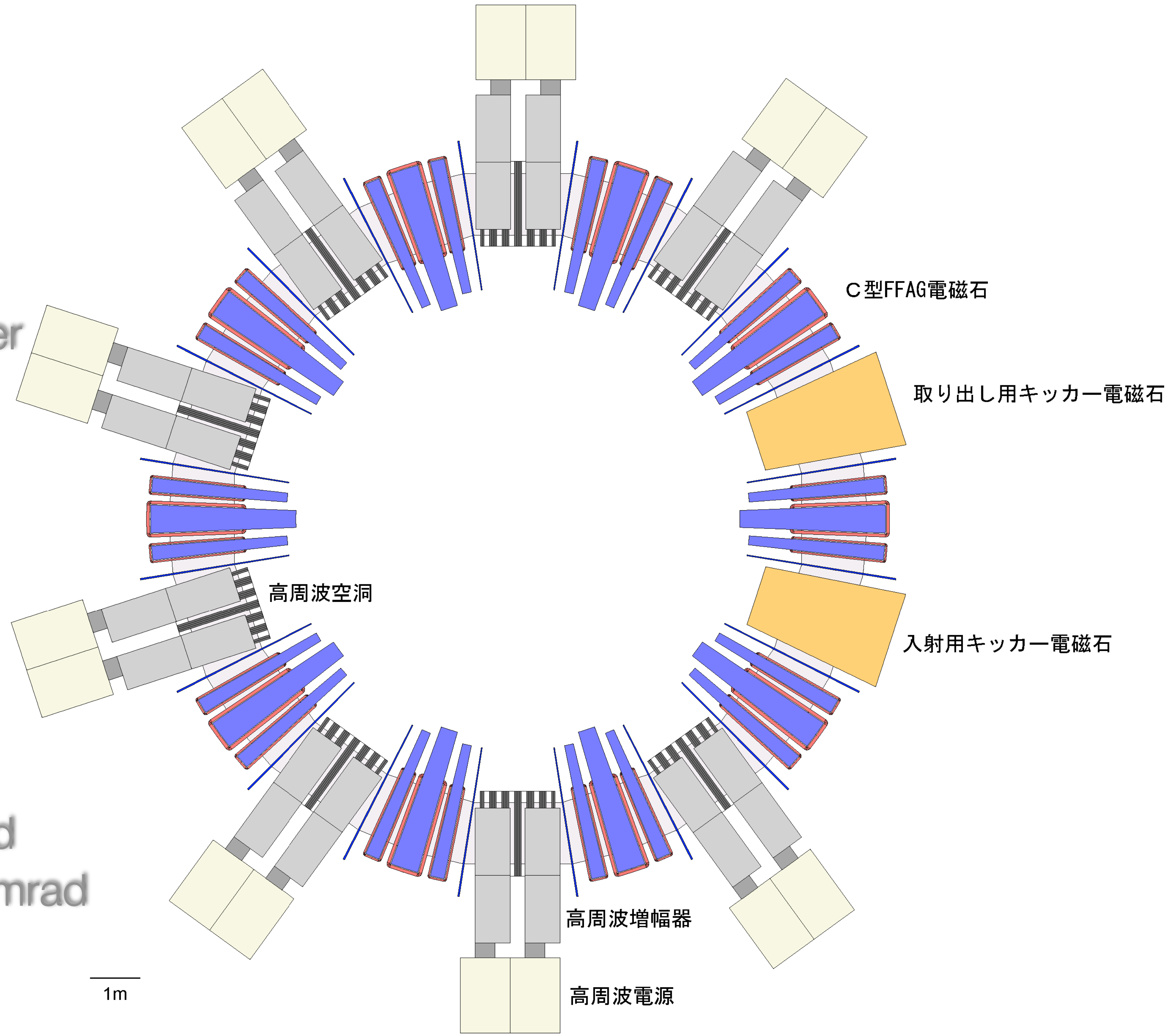
PRISM FFAG Ring R&D

A portion of the PRISM-FFAG ring is under construction at Osaka University.



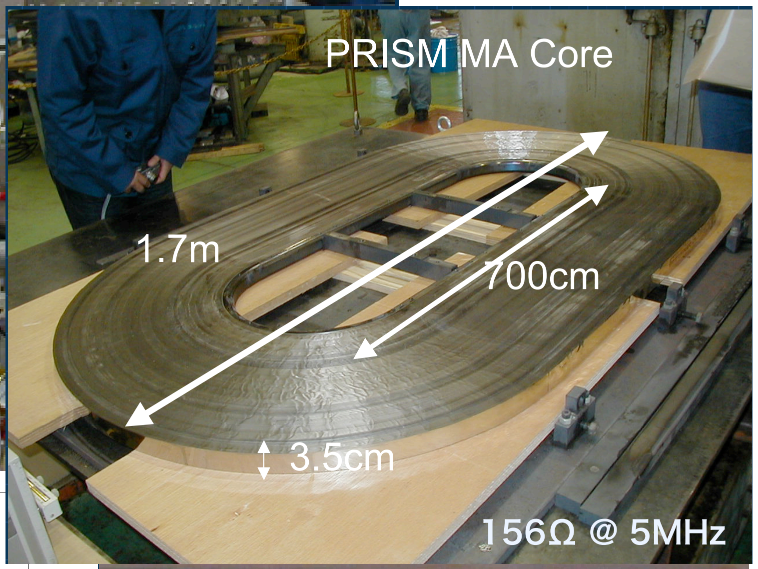
PRISM FFAG Lattice Design

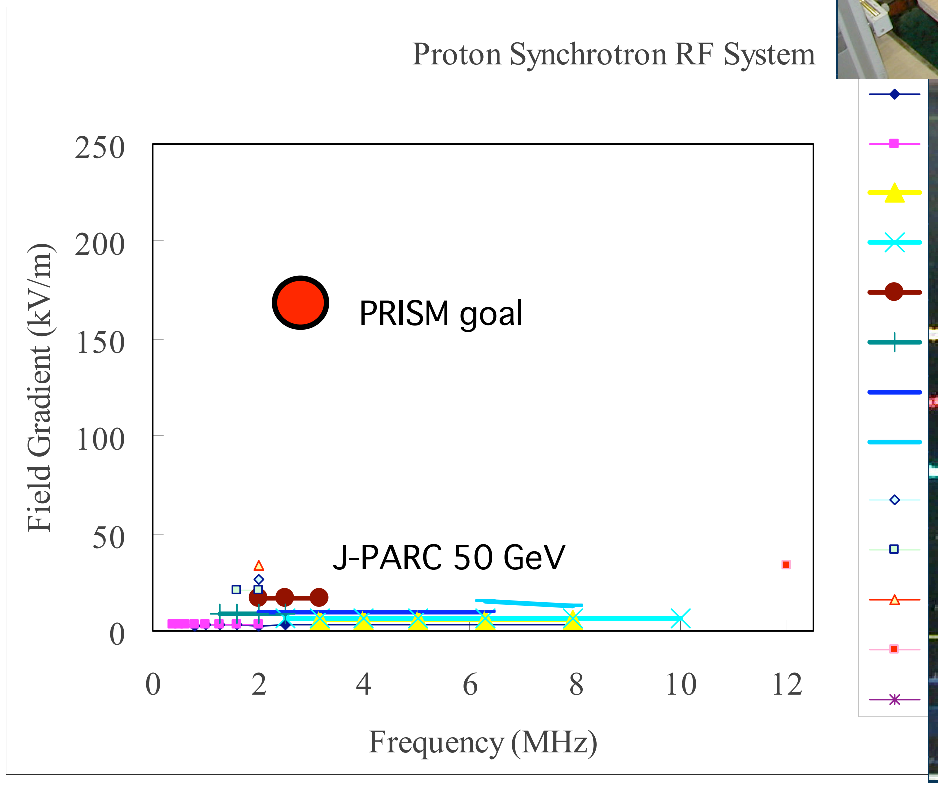
- 10 cells
- k=5(4.6-5.2)
- F/D(BL)=8
- r0=6.5m for 68MeV/c
- half gap = 15cm
- mag. size 110cm @ F center
- Triplet
  - θ_F=4.40deg
  - θ_D=1.86deg
- tune
  - h : 2.86
  - v : 1.44
- acceptance
  - h : 140000 π mm mrad
    - --> 40000 π mm mrad
  - v : 6500 π mm mrad

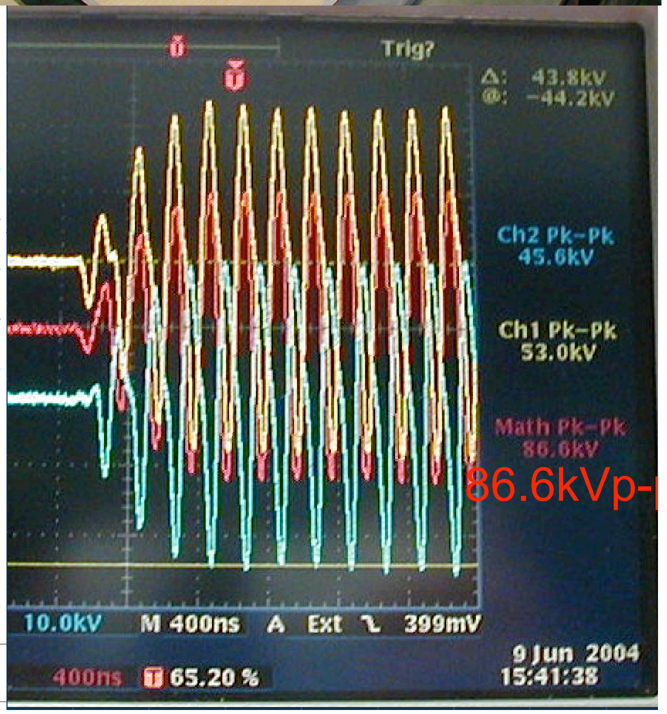


PRISM FFAG R&D is Going...

PRISM FFAG R&D is Going...

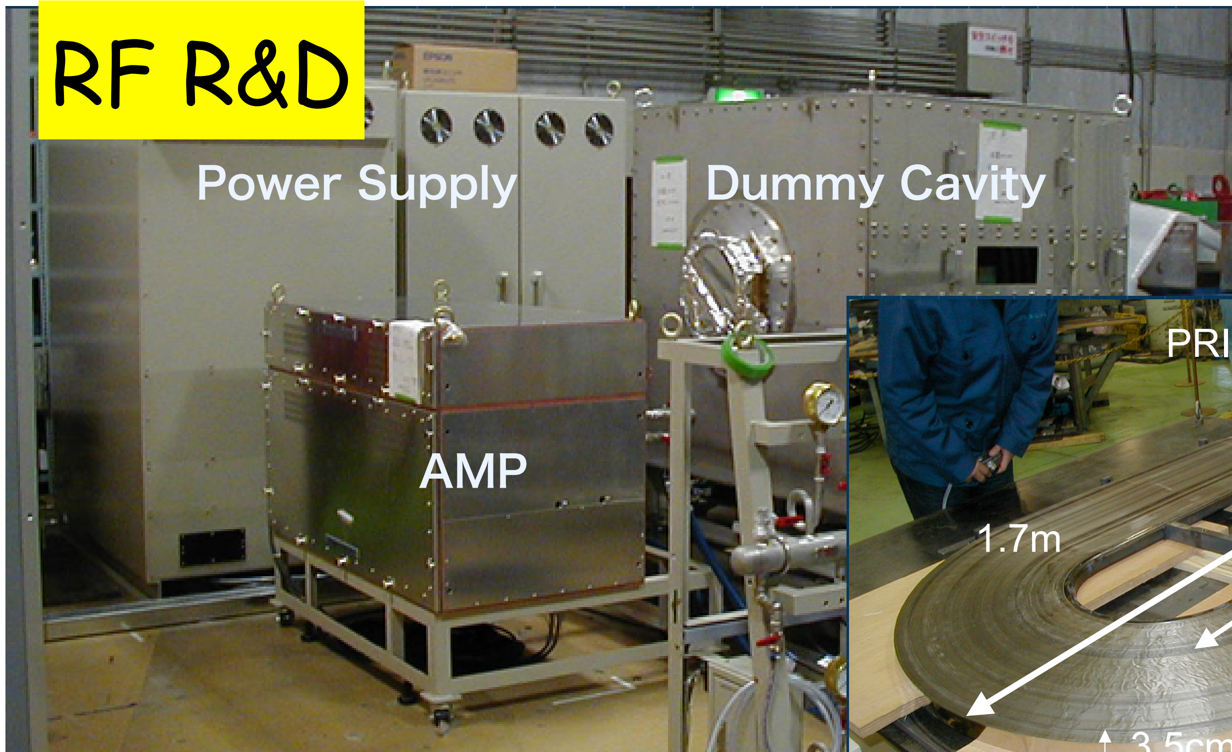


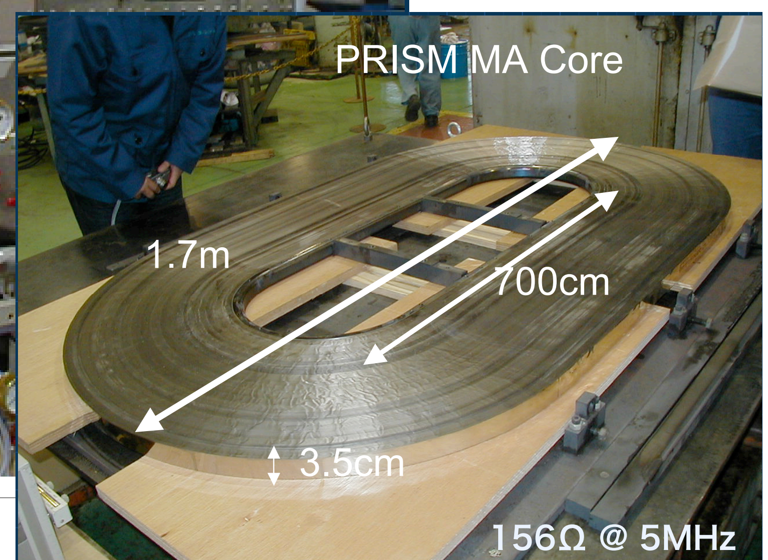


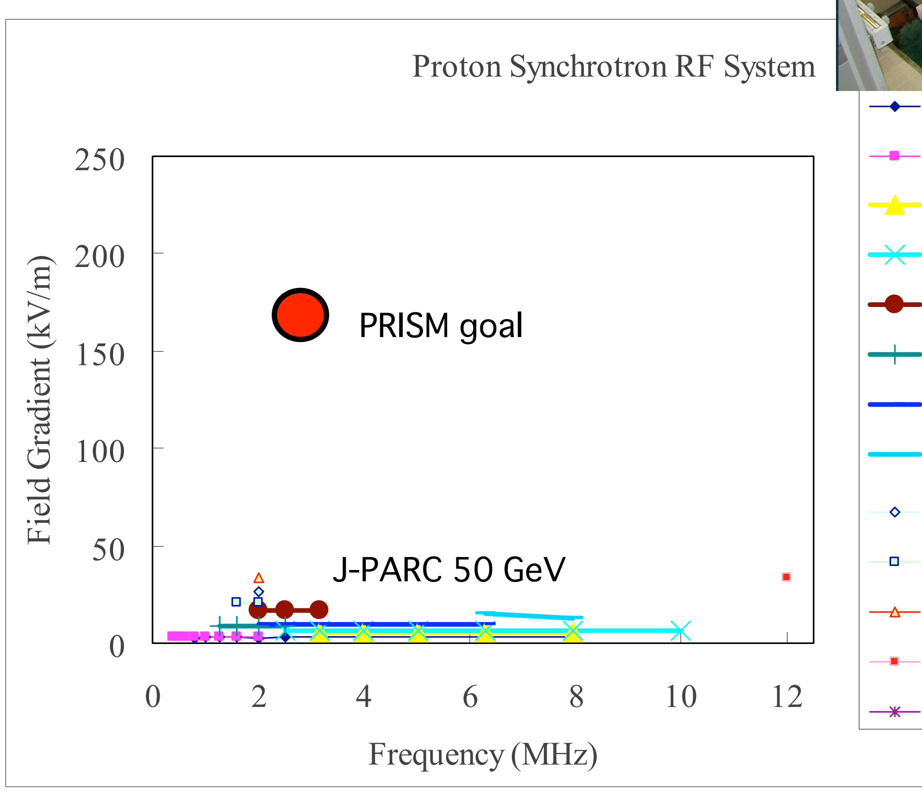


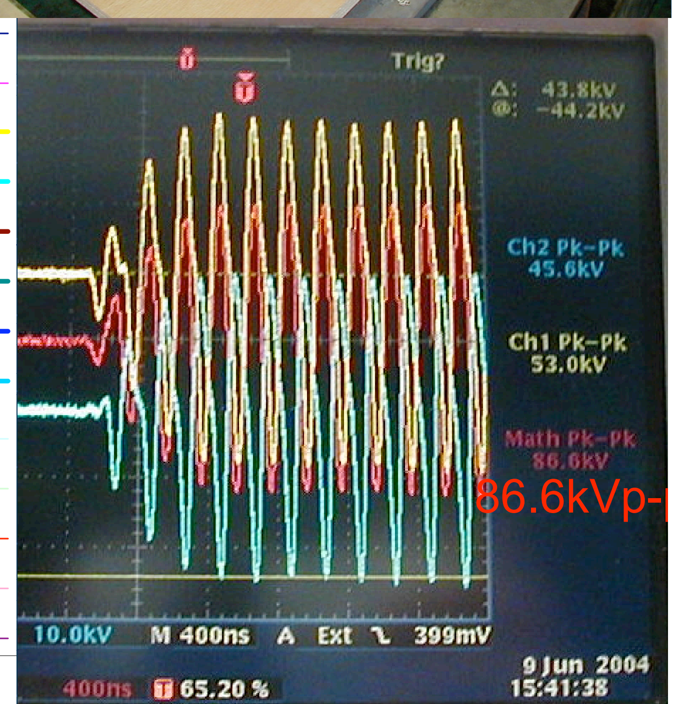
PRISM FFAG R&D is Going...

RF R&D

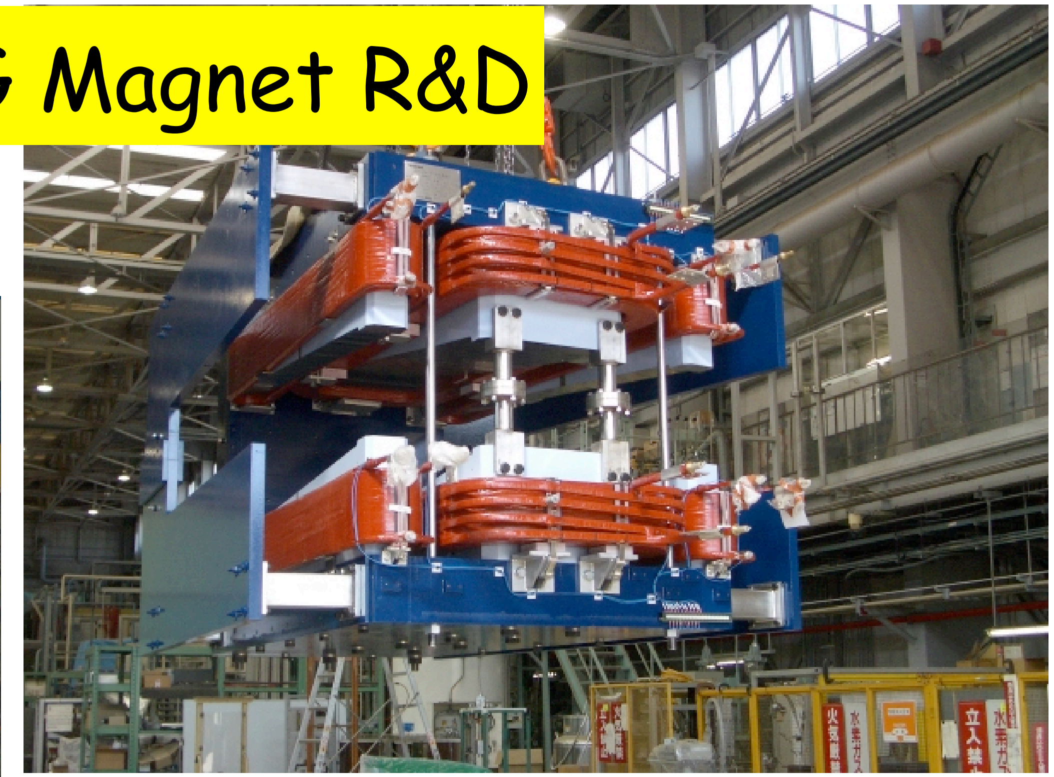


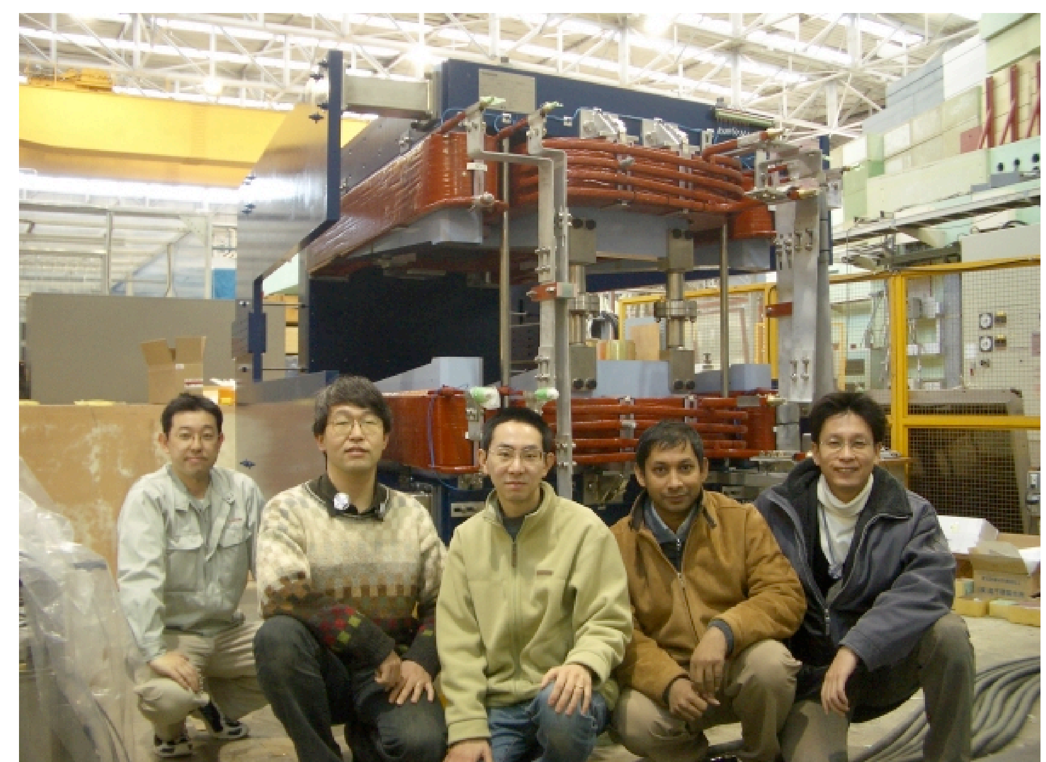






FFAG Magnet R&D



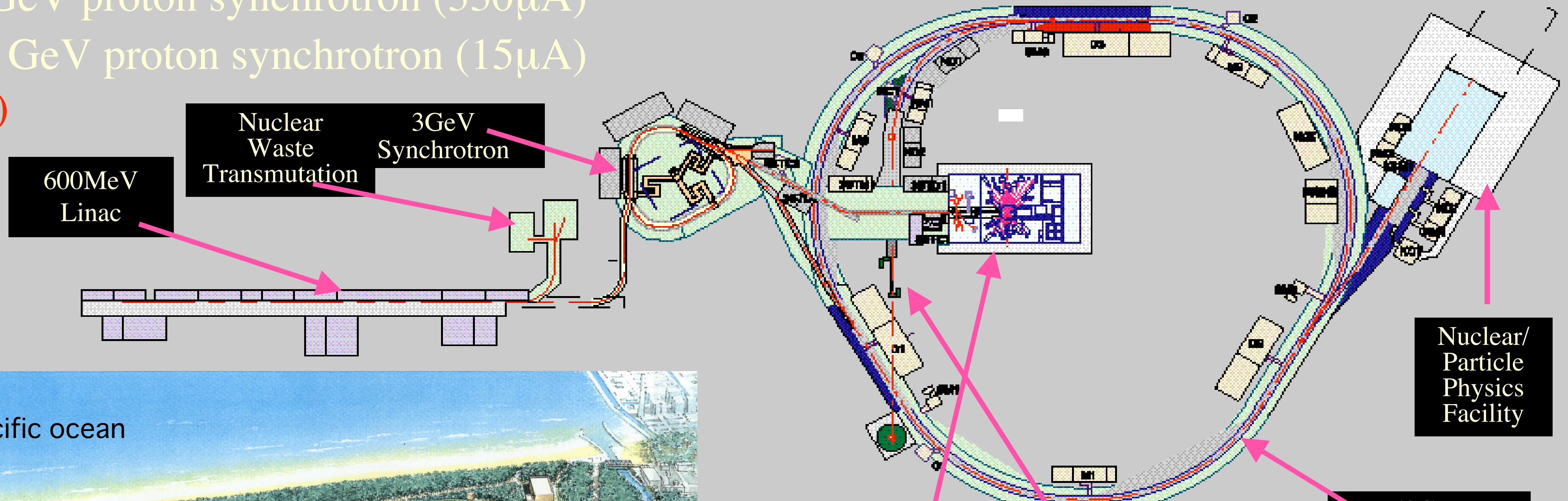


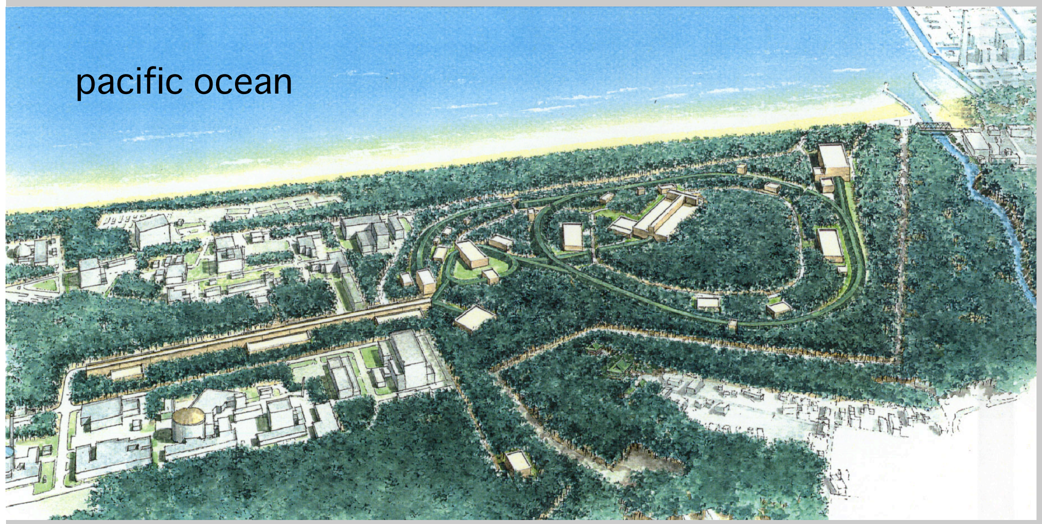
Prospects

PRISM/PRIME at J-PARC

400 (200) MeV proton linac
3 GeV proton synchrotron (330μA)
50 GeV proton synchrotron (15μA)
(40)

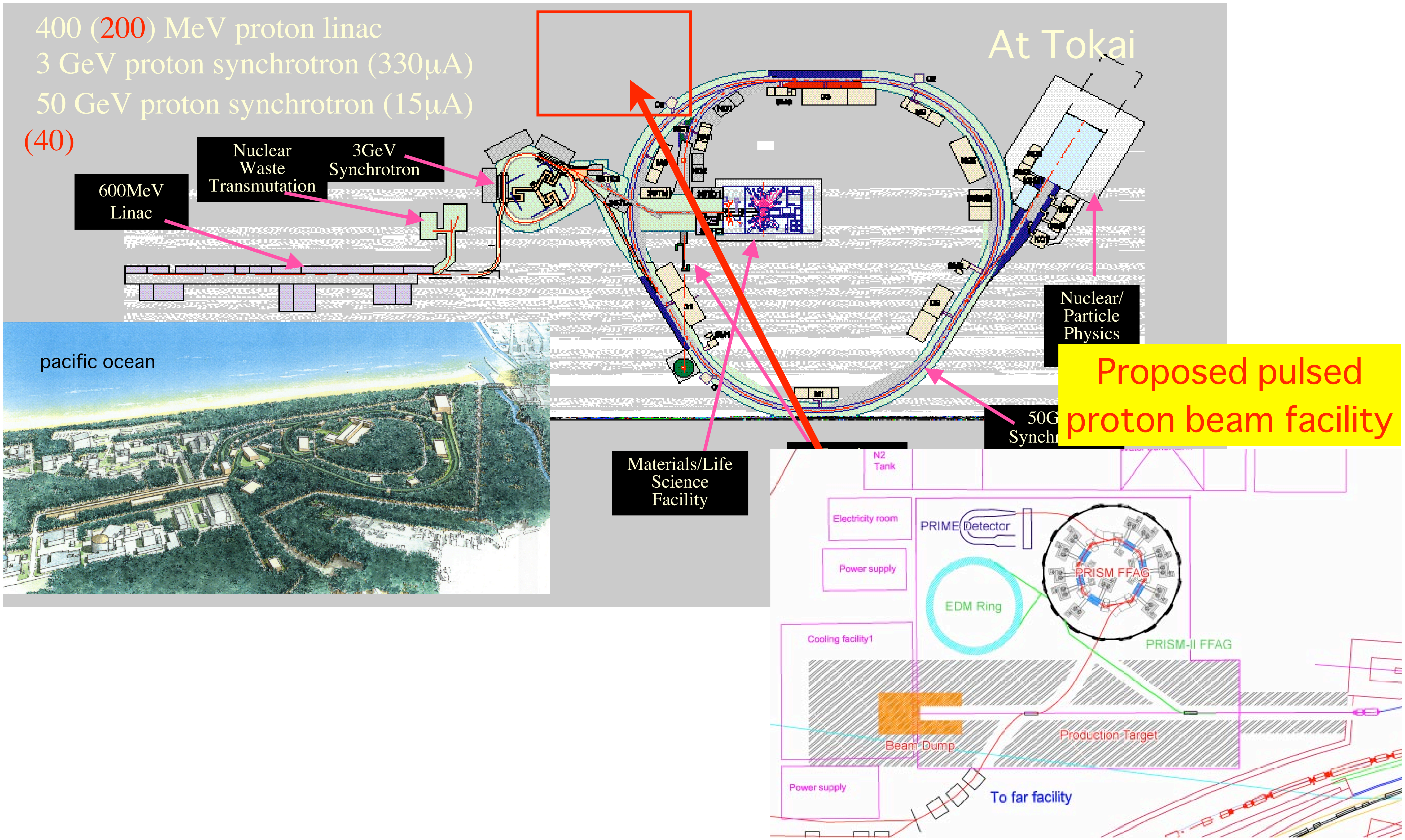
At Tokai





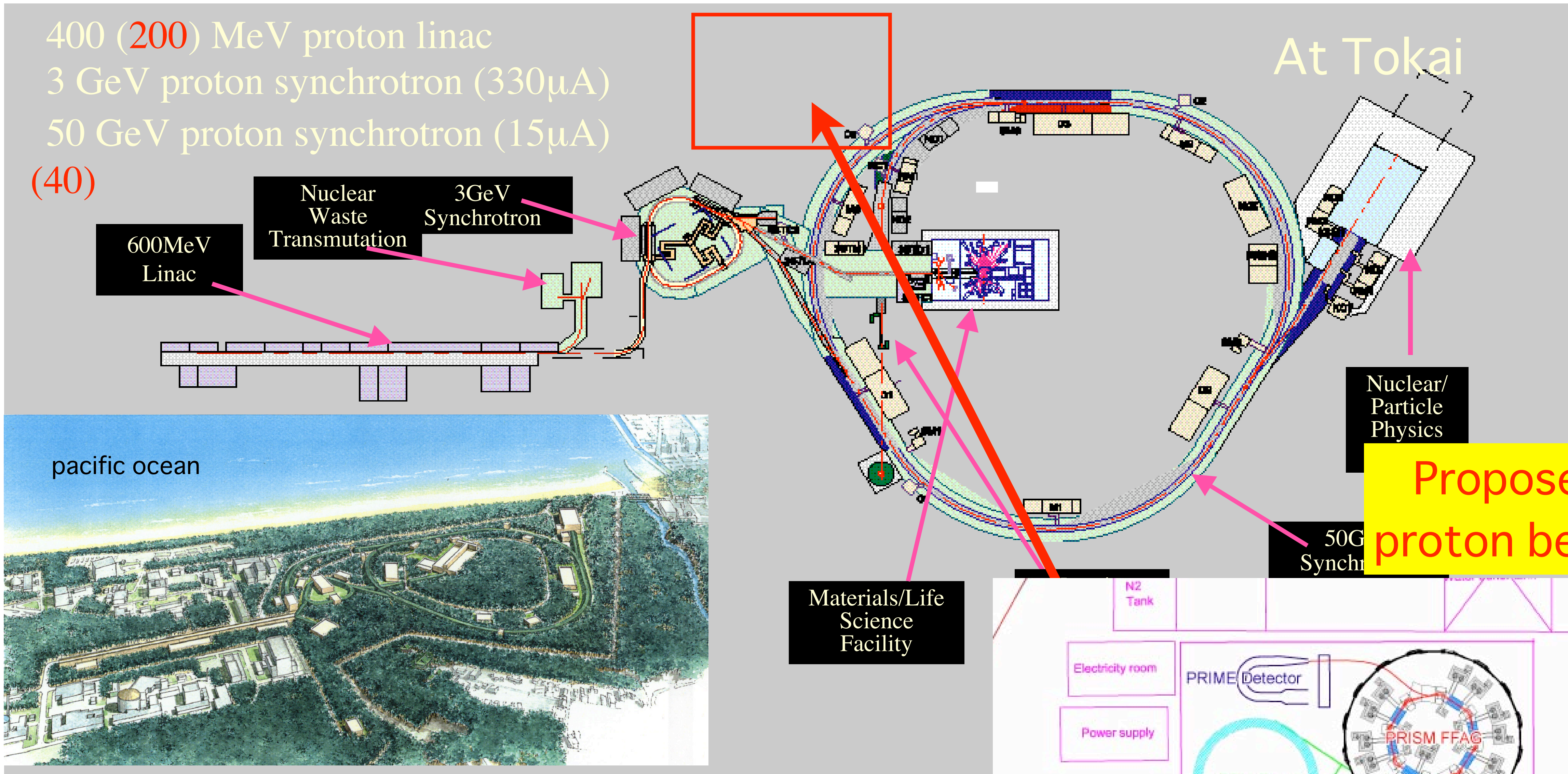
J-PARC = Japan Proton Accelerator Research Complex

PRISM/PRIME at J-PARC

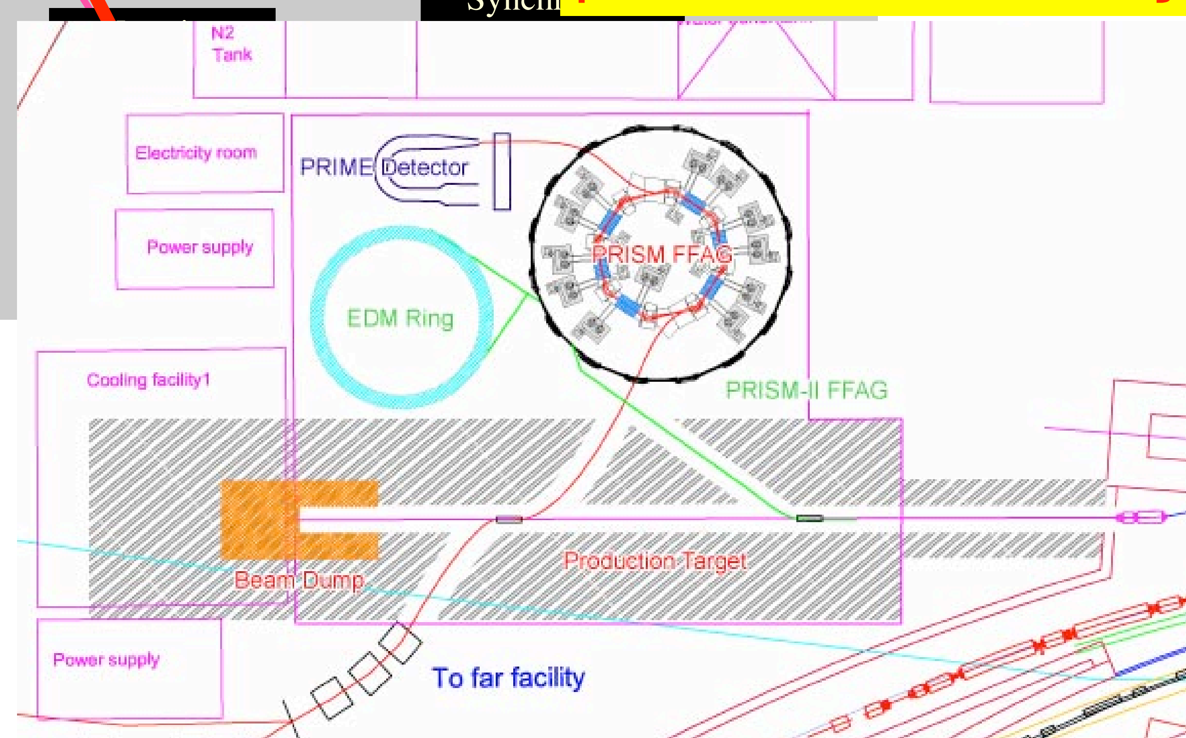


J-PARC = Japan Proton Accelerator Research Complex

PRISM/PRIME at J-PARC

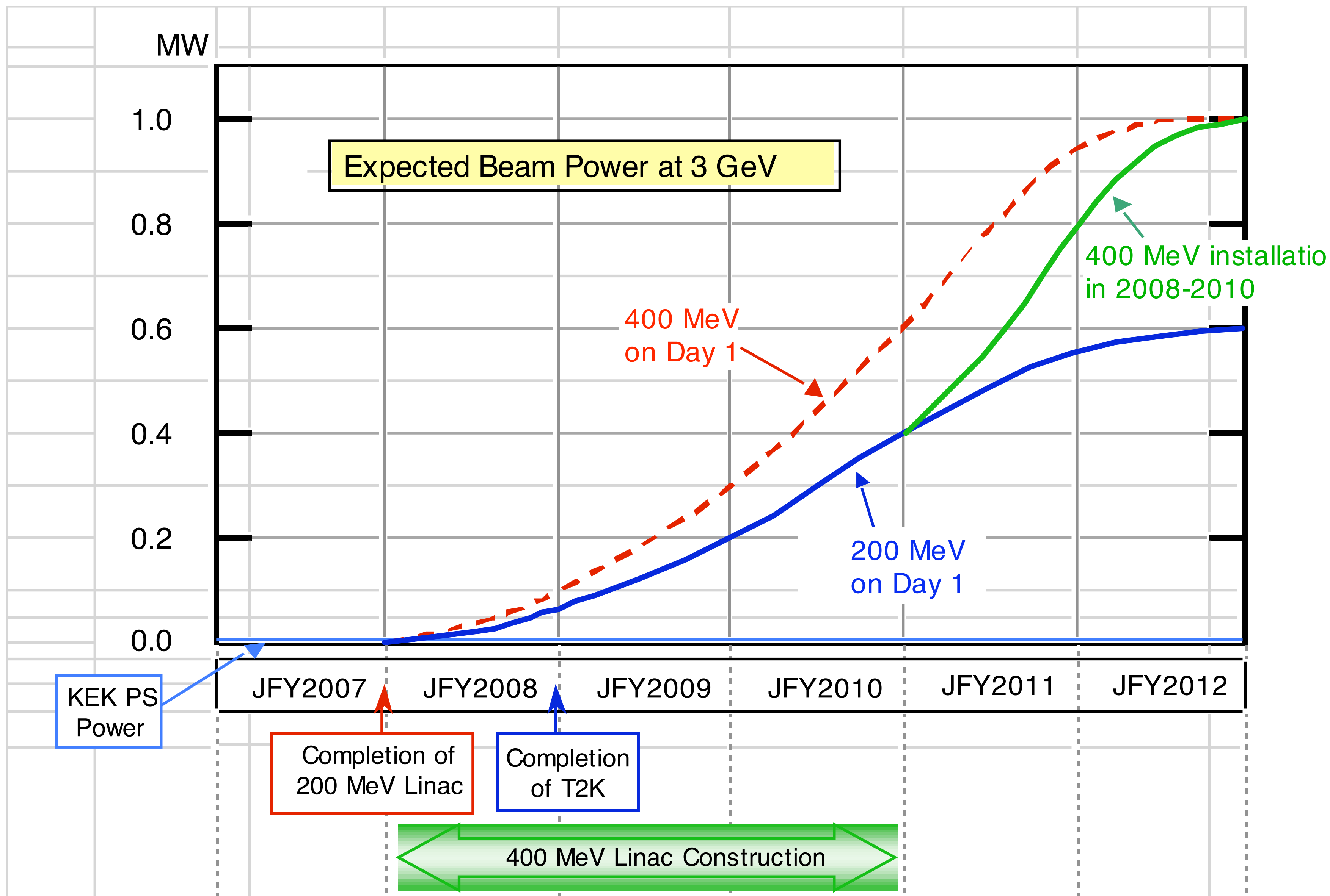


Proposed pulsed proton beam facility



This pulsed proton beam facility has not yet been funded.

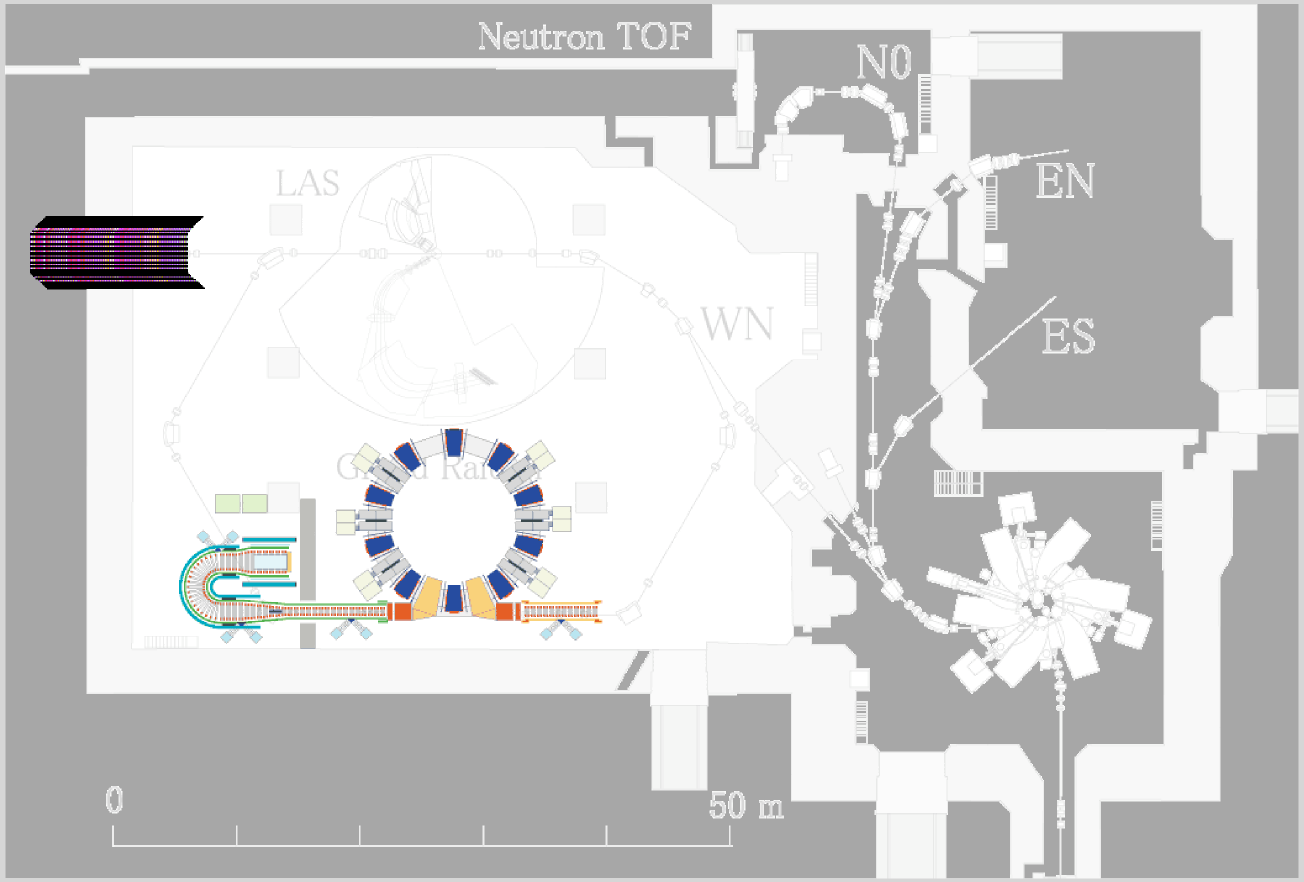
J-PARC Beam Power Improvement Schedule



	JFY2007	JFY2008	JFY2009–JFY2012
3 GeV Neutron and Muon	Construction	Beam Test	Usage for Experiments
50 GeV Nuclear - Particle	Construction	Usage for Experiments	
T 2 K Experiment	Construction		Usage for Experiment

One Strategy

- Phase I :
  - build PRISM+PRIME at the Research Center for Nuclear Physics (RCNP), Osaka University. There is a 400 MeV proton cyclotron with a few micro A.
  - test PRISM+PRIME.
- Phase II :
  - Bring PRISM+PRIME to a high intensity proton driver to carry out an experiment.
- funding requests in JFY2005 and JFY2006 failed.
- New strategy is needed !



RCNP at
Osaka University

History and Prospect

- January 2003 : LOIs of PRISM (LOI-24) and PRIME (LOI-25) were submitted to KEK.
- January, 2006 : LOI of PRISM/PRIME were submitted to J-PARC PAC.
- Fall, 2006 : review committee on LFV physics at KEK
- January, 2007 : J-PARC PAC ?

Summary and Outlook

- PRISM/PRIME is a site-independent muon facility and a detector.
- PRISM needs a high intense proton beam (>0.6 MW).
- PRISM has the following features.
  - no pion backgrounds in a beam.
  - no beam related backgrounds (beam electrons, anti-protons...)
  - no proton extinction is needed.
  - no cosmic ray background (10^4 suppression).
  - narrow beam energy spread.
- The PRIME detector has capability to reduce detector rates even with 100-1000 Hz beam repetition.
- However, more studies and R&D are needed.
- Works (including funding requests) in Progress......

End of My Slides